REPORT OF

THE HIGH LEVEL COMMITTEE ON FLOODS

VOLUME I

GENERAL ASSESSMENT PRINCIPLES AND POLICIES

Government of India

MINISTRY OF IRRIGATION AND POWER

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Government of India

MINISTRY OF IRRIGATION & POWER

HIGH LEVEL COMMITTEE ON FLOODS

No. 1/1/57-*HLCF* *New Delhi, the* 30th *December,* 1957

From

Shri Balwant Singh Nag, I.S.E.,
Member-Secretary,
High Level Committee on Floods.

To

The Secretary to the Government of India,
Ministry of Irrigation & Power,
New Delhi.

Sir,

In order to have an adequate assessment of the flood problem in the country and also an authoritative advice on the measures that should be taken to tackle it, the Government of India decided *vide* Ministry of Irrigation and Power Resolution No. DW. V. 530 (1)/56, dated the 12th April 1957 to set up a Committee of the following officers to go into the entire question on the basis of the available data :—

(i) Shri A. C. Mitra, I.S.E.,
Chief Engineer, Irrigation, Uttar Pradesh
(In addition to his duties as
Chief Engineer in charge of Rihand Project). — *Chairman*

(ii) Shri B. S. Nag, I.S.E.,
Chief Engineer, Floods, Assam. — *Member*

(iii) Shri C. R. Ranganathan,
Rtd. Inspector General of Forests. — *Member*

(iv) Shri M. P. Mathrani, I.S.E.,
Chief Engineer, Bihar.
(Part-time for Bihar only.) — *Member*

(v) Shri R. D. Dhir, I.S.E.,
Chief Engineer, Floods,
Central Water & Power Commission. *Member-Secretary*

(vi) One or two foreign experts.

2. The terms of reference of the Committee were specified as follows :—

(a) To analyse the factors responsible for a succession of heavy floods in the Ganga and the Brahmaputra basins in the recent years and to indicate, in a general way, after an examination of the hydrological and other relevant data available, the lines on which the flood problems in the various areas should be tackled.

(b) To review the measures undertaken in the last two years to combat floods and to indicate the lines on which work should be prodeeded in future both in regard to the construction of flood protection works and in regard to the collection of data for the formulation of long-term flood control measures.

(c) To lay down principles for the fixation of priorities in the construction of flood protection works.

(d) To examine specific flood problems of an acute character from States like Andhra, Orissa and the Punjab and to indicate the lines on which they should be tackled.

(e) To report on the circumstances in which embankments can be considered as a suitable method of flood protection.

(f) Any other recommendations bearing on the control of and mitigation of damage by floods.

3. Shri Dhir assumed charge of his assignment on 22nd April 1957. Shri Nag joined on 30th April 1957. Shri Ranganathan did not find it possible to join the Committee and the post remained unfilled until Shri N. P. Mohan, retired Chief Conservator of Forests, Punjab, was appointed instead and assumed charge on 5th June 1957. Shri Dhir was entrusted with the duties of Chief Engineer, Floods (Planning and Designs), Central Water and Power Commission with effect from 28th August 1957. He thus became a part-time Member of the Committee. In consequence, Shri Balwant Singh Nag was given the additional duties of the Secretary of the Committee. Shri N.P. Mohan resigned his appointment and was relieved on 30th September 1957.

4. There was an unforeseen delay in securing the services of a foreign expert. Ultimately Mr. H. E. Hedger, Chief Engineer, Los Angeles County Flood Control District, joined the Committee on 20th November 1957.

5. The Committee have divided their Report into four volumes as under :

Volume I	—	General assessment, principles and policies.
Volume II	—	Flood control in various river basins.
Volume III	—	Graphs.
Volume IV	—	Maps.

6. Volume I and III are submitted herewith. The maps contained in Volume IV pertain to Volume II and these two volumes will be submitted later.

7. Volume I deals with the following terms of reference :

(i) Part reference (a), namely an analysis of the factors responsible for succession of heavy floods in the Ganga and the Brahmaputra basins in recent years, in Chapter IX.

(ii) Reference (c) in Chapter VIII.

(iii) Reference (e) in Chapter V.

(iv) Reference (f) in Chapters I to IV, VI, VII and X.

8. The Committee considered that a discussion of subjects like nature of flood problem in India, past efforts on flood control, flood damages, place of flood control in five-year plans, methods of flood control, soil conservation and organisational aspects, was both relevant and important, and dealt with these matters in various chapters under Reference (f).

9. The report and the recommendations made therein are summarised in Chapters XI and XII respectively. Also a statement by Mr. H. E. Hedger is given at the end. He agrees with the views expressed by the Committee.

10. The remaining terms of reference will be dealt with basin-wise in Volume II.

11. The Committee take this opportunity to place on record their deep appreciation of the assistance rendered by officers of the Survey of India, the India Meteorological Department, the Central Soil Conservation Board and the Flood Wing of the Central Water and Power Commission.

Yours faithfully,

BALWANT SINGH NAG

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CHAPTER I

The Nature of Flood Problem in India

1.1. Introduction

1.1.1. The flood problems in the country can be categorised as under:

(1) Inundation due to
  - (i) overflow of banks;
  - (ii) obstructions on account of blocking of natural streams or congestion at outfall;
  - (iii) inadequate land drainage of low lying areas;
  - (iv) sea tides.

(2) Erosion of river banks.

(3) Change of river course
  - (i) avulsions;
  - (ii) oscillation.

1.1.2. Inundation can be caused by a number of factors. When there is excessive precipitation and inadequate channel capacity to carry the flood waters, the rivers overflow their banks. Even when flooding is not due to excessive precipitation, inundation can occur on account of obstruction in the stream. Inadequate waterway at road and rail crossings or other encroachments aggravate flooding by causing afflux. Flooding can also occur due to congestion at confluences. Besides, rain water may stagnate on low lying areas for want of proper drainage. That, however, is essentially a drainage problem. Tides resist flood flows of rivers and thus accentuate inundation. Although the tide period in itself may be relatively small, it takes the inundated area much longer to drain back and in the meantime the next tide intervenes. Prolonged flooding thus results.

1.1.3. Another category of the problem posed by floods is bank erosion. This erosion may adversely affect vast stretches of fertile agricultural land on the river margins or it may affect townships or urban concentrations involving damage to industry, vital communication lines, etc.

1.1.4. Changes in river courses often complicate flood problems. Instability in the upper reaches of a river basin can accentuate the operation of erosive factors, thus increasing the sediment charge in a river. With abrupt variation

in bed gradients and heavy sediment charge, rivers sometimes develop tendencies for changing their course to join a neighbouring stream. These are cases of avulsions. Another category of change of river course is typified by oscillatory beds, where the rivers emerging from a gorge swing from side to side in the flood plain within more or less specified limits. The Kosi is the typical example.

1.1.5. Such general characteristics of the flood problem in India are generally known and perhaps can even be elaborated. But, effective action requires a study of the specific characteristic of the problem in specific problem areas. Such an understanding is an important prerequisite for an adequate comprehension of the nature and magnitude of the problem in the country.

1.2. General Review

1.2.1. For a comprehension of the nature of the flood problem, India can be divided into the following four regions :

North Western Rivers System.
Ganga River System.
Brahmaputra River System.
Peninsular Rivers System.

This classification is based on broad regional similarity of the areas in respect of meteorological, geological, topographical and the resulting hydrological characteristics of the rivers and their tributaries.

1.2.2. *The North Western Rivers System*

The North Western Rivers System essentially comprises the Indus basin and its tributaries, namely the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej. The Jhelum valley in Kashmir is saucer-shaped. All precipitation in the valley and its catchment finds its way into the Jhelum which has a single outlet near Baramula through which it flows out after passing through the Wullar lake. The urban and agricultural areas are situated mostly at lower elevations in the valley, with the result that their protection becomes a problem. The three important problems in the Kashmir valley are (i) the protection of Srinagar town; (ii) the protection of the low lying agricultural areas along the Jhelum and (iii) the prevention of an undue rise of the lake level in Wullar which, if unchecked, leads to the submergence of considerable areas of fertile marginal land. In the Jammu valley, the principal rivers on which there is the flood problem are the Chenab, the Tawi and other tributaries; but, the flood problem of the Jammu valley is relatively less acute than that in the Kashmir valley. The Ravi, the Beas and the Sutlej overflow their banks in some areas

in the Punjab. But, by far the most important problem in the Punjab is one of improving the drainage of incident rain. In the area between the Ravi and the Beas, which might otherwise be called the Bari Doab area, the problem is one of preventing spill and the provision of adequate drainage facilities. In the area between the Beas and the Sutlej which might otherwise be called the Bist Doab area, the main problem is one of arresting erosion in the Sivalik hills. In the area between the Sutlej and the Ghaggar, the problems are arresting erosion in Sivalik hills, preventing spill, and improving drainage. In the Ghaggar tract itself, the problem is entirely one of drainage.

1.2.3. *The Ganga River System*

1.2.3.1. The western-most tributary of the Ganga is the Yamuna which, rising in the Himalayas, flows down for some length as the boundary between the Punjab and the U.P. till it joins the Ganga at Allahabad. Although there has been some flood damage in the Yamuna basin below the Okhla weir, the main problem, by and large, is between the Tajewala and the Okhla weirs and of arresting erosion in the Sivalik hills.

1.2.3.2. The basic problem in the Yamuna in this reach is one of preventing large peripheral spill. If the spill is sought to be prevented by embankments, there are apprehensions that the resulting elimination of the valley storage is likely to accentuate flood heights lower down in the vicinity of Delhi. The significance of the flood control problem in the Yamuna arises out of the fact that the Yamuna in this reach is a boundary between two important States—the Punjab and U.P. The river flows through several States like the Punjab, Delhi and U.P. and there is the fact that the agricultural areas affected by the floods are very highly developed and hence very valuable. Floods in the Yamuna would interfere with important communication lines like the Northern Railway Bridge at Delhi and the Grand Trunk Road between Delhi and Calcutta. It will be no exaggeration to suggest that proximity to the country's capital lends additional importance to the problem posed by the Yamuna floods.

1.2.3.3. To the east of the Yamuna lies the important river Ganga. In its north-south flow in the initial stages in the West U. P., the Ganga does not pose any serious flood problem. The flood problem in the Ganga basin is much lower down as it flows through the cities of Kanpur, Allahabad, Benaras and Patna into West Bengal and as it receives its tributary contributions from other important rivers. On the main stem of the Ganga river, it is predominantly a problem of preventing spill, the simplest solution for which is the construction of embankments, but considerable relief on the main stem can be achieved by flood control on large-sized tributaries of the Ganga.

1.2.3.4. The rivers Gomti, Tons and Sai lie between the Ganga and the Ghaghra. These rivers do not drain from the Himalayas. The flood waters in these rivers are mostly derived from excessive local precipitation and prevention of inundation is the chief problem.

1.2.3.5. The Ghaghra is an important tributary of the Ganga and has itself got big river systems like the Sarda and the Rapti as its tributaries. In addition to a fairly large-sized Himalayan catchment, the Ghaghra and its tributaries have considerable drainage areas in the plains portions, south of the Himalayas in Nepal and U.P. Besides over-bank spill in several reaches along their course, the Ghaghra and its tributaries also erode their banks at several places. Another distinguishing feature in East U.P. is the aggravation of the problem by flood congestion, notably in the areas in the vicinity of the confluences. For instance, near the confluence of the Rapti with the Ghaghra, there is a zone which is perpetually inundated in the monsoon period as a result of flood congestion. Similar is the situation where the Ghaghra joins the Ganga.

1.2.3.6. Further to the east, the Gandak has a fairly large-sized Himalayan catchment. The problems presented by the Gandak are two-fold. The first is the overflow in the upper reaches in Nepal and the second is the extensive bank erosion in the reach where the river is a border between U.P. and Bihar. Overflow in the upper reaches not only inundates its own river margin, but the flood waters escape through drainage basins into western river systems like the Rapti. But, by and large, the Gandak is a fairly stable river and has adequately been embanked for a greater portion of its length. The drainage channels in the Gandak valley do not shift or meander very much. The area between the Gandak and the Ghaghra and that between the Gandak and the Burhi Gandak is drained by innumerable small drains. These drains are interfered with by local people for irrigation or fishing. Such artificial interference with the drainage system of these rivers, when in floods, accentuates the flood problem. Moreover, in these two areas, there are a number of low lying depressions which do not get drained out for a long time.

1.2.3.7. To the east of Burhi Gandak lies the Adhwara zone which is drained by a number of rivers which are collectively known as the Adhwara group, the two most important of which are the Bagmati and the Kamla. The Adhwara group of rivers has only a small catchment in the Himalayan region. The problem in the Bagmati is one of preventing spill in the middle reaches. Similar is the case with the Kamla system. An additional complication in this region is the transfer of flood flows from one river basin to another, because of the nature of the terrain. The Bagmati passes some of its flood flow to the Burhi Gandak. The rivers in this region have been mostly erratic and have been

changing their beds, which is believed to be attributable to the enormous detritus they carry from the unstable steep slopes of the Himalayas. A recent example of such river behaviour is the avulsion of the Kamla when it left its own course to join the Kosi higher up.

1.2.3.8. The erratic behaviour of the Adhwara river system is magnified several-fold in the case of the Kosi which is notorious for its vagaries. Kosi carries large quantities of coarse sediment and is a good example of a river with an oscillatory bed.

1.2.3.9. The eastern-most river in the Ganga system is the Mahananda. But, from the viewpoint of flood control, it does not offer serious problems. A few town protection schemes and marginal embankments might solve the problems of this river to a great extent.

1.2.3.10. Southern tributaries of the Ganga do not generally pose any serious flood problems.

1.2.3.11. The areas in the valleys of the rivers Bhagirathi, Hooghly, Damodar, Ajoy and Roop Narain present problems, chiefly of bank erosion affecting towns situated on the banks of these rivers. There is no serious inundation problem because the area is adequately protected by embankments. However, in years of heavy rainfall, the drainage problem may become acute.

1.2.3.12. The Sunderbans area of West Bengal comprising the southern portion of the district of 24 Parganas presents problems peculiar to itself. The area is interwoven by innumerable tidal creeks and rivers connecting the major estuaries, namely the Hooghly, the Bertola, the Saptamukhi, the Thakuran, the Matla, the Raimongal and the Kalindi. During the monsoon months, the upland flood water discharges into the Bay of Bengal through the Hooghly and the Kalindi, while the others carry the drainage from their respective basins. The Sunderbans rivers are all tidal, the Perigean tides occuring twice in the year during the months of April and October when the moon is nearest to the earth. The rise in flow in the course of the day is much more in the spring tide period than in the neap tides. The spring range of tides in the Perigean tides varies from 15′ to 18.5′ and the tide level reaches the maximum in all tidal rivers at this time of the year. When the upland flood synchronises with the Perigean tides, breaches occur in the embankments along tidal rivers, causing damage to crops worth lakhs of rupees.

1.2.4. *The Brahmaputra System*

1.2.4.1. The Brahmaputra basin is bounded on the north by the Himalayas, on the east by the Patki range of hills and on the south by the Assam range

of hills. The catchment of the Himalayan ranges, both in spread and height, are much larger and as rainfall is also higher than on the Assam range of hills, many of the north bank tributaries of the Brahmaputra are very much larger than those on the south bank. Their characteristics are also basically different. They have very steep slopes, and shallow braided channels over a considerable distance from the foothills; have coarse sandy beds and heavy silt charges. They generally have flash floods. The south bank tributaries have got comparatively flatter slopes and deep meandering channels, almost from the foothills. Their beds and bank are formed of fine alluvial soil and the rivers carry a relatively low silt charge.

1.2.4.2. The Teesta and the Torsa are two of the Himalayan tributaries of the Brahmaputra which drain Bhutan and Sikkim and flow through North Bengal into East Pakistan to join the main river. These rivers do not cause much damage in the mountainous Bhutan and Sikkim, but do so after entering North Bengal. They are heavily silt laden, and the silt charge is so heavy that sometimes bridge openings silt up to crown of arches. Control over the sediment load of these streams will be an important factor in mitigating flood damage in this area. In addition to inundation, these rivers erode their banks extensively and cause much damage to townships and tea plantations. Added to this, these rivers change their course very frequently in the plain, thereby encroaching upon new areas. The rivers in the district of Malda in West Bengal drain into the Ganga. The problem there is one of submersion of low lying areas.

1.2.4.3. But, by and large, the flood problem in the Brahmaputra basin lies in the Assam valley and along its tributaries. The river maintains a braided channel throughout its length in Assam and flows in a number of channels and cross-channels between its high banks. There is a constant silt movement resulting in the shifting of the channels and the sand shoals and causing bank erosion. Along most of its length, the deep channel of the Brahmaputra hugs the southern bank, presumably because of the heavy flood discharge and excessive sediment in the northern tributaries which tend to push the river further south.

1.2.4.4. The bed slope of the Brahmaputra in Assam valley is steep for a river of its size. Between Kobo and Dibrugarh, it is 1.4′ per mile; between Dibrugarh and Nemati it is 0·9′ per mile; and, between Nemati and Gauhati 0·7′ per mile. At the confluence of the three major tributaries, the Dihing, the Dibang and the Luhit, which go to form the Brahmaputra, the bed has become abnormally wide since the earthquake of 1950. The bed has risen there by more than 10′ due to the deposition of detritus, making the river shallow and wide.

1.2.4.5. When the Brahmaputra is in high flood, it backs up its tributaries and makes them spill near their outfall. Apart from such congestion, the tributaries themselves in most cases spill over their banks during high floods. As in the case of the Brahmaputra, all the tributary channels have also raised their banks, the ground sloping away from them and creating a subsidiary valley between two major tributaries. This subsidiary valley drains the local rainfall between the two rivers and any flood spill from the rivers on either side.

1.2.4.6. Lateral shifting of the Brahmaputra which has been going on through the ages is still in progress. The movement is in southerly direction. Besides the river attacks its banks here and there through active erosion, resulting in considerable loss of land every year. It was particularly severe soon after the earthquake of August 1950, because excessive silt brought down by the river from the hills after that event completely upset the regime of the river, particularly in its upper reaches. The maximum erosion is experienced in the falling stages of floods.

1.2.4.7. Erosion on these tributaries is no less serious than along the Brahmaputra. It is more severe on the tributaries carrying a greater percentage of silt.

1.2.4.8. It will be pertinent to briefly touch upon the problems of Tripura and Manipur in this context. Of the two Union Territories, Tripura has an important and serious flood problem.

1.2.4.9. Tripura is a level alluvial plain mostly cultivated, except for some areas in the isolated Lalmai hills. It is intersected in all directions by rivers. The drainage passes west and south-west from the watershed in the hills of Tripura and finds an exit either in the Meghna river or in the Bay of Bengal. The Meghna sweeps past the western border and is 4 miles in width. The important rivers which cause flooding in Tripura are the Haora, the Khowai the Gumti and the Manu. Some of the rivers are navigable throughout the year. In all, about 630 miles of rivers in Tripura are navigable throughout the year and over 460 miles more during the rains. In fact in the rainy season, the roads are little used and the people move about and transport their goods mainly by water.

1.2.4.10. The protection of Agartala town is one of the important problems of the territory and certain embankments have been constructed around the city for this purpose. The problem is one of an examination of the rational alignment of the bunds and ensuring that the bunds do not cause new problems after solving the old ones.

1.2.4.11. There are four small rivers in Manipur territory. The discharges range from 1,000 to 12,000 cusecs. They overflow their banks here and there but not so much as to cause serious damage. On the other hand, it is believed that their silt has a fertilising value and hence this is generally welcomed by the cultivators. The flood problems of Manipur territory are, therefore, not of a serious nature, although the constricted outfall from the Logtak lake creates a problem of submergence of marginal lands. In fact, in the State as a whole, an exploitation of the possibilities of production of hydro-electric power seems to have higher priority than flood control.

1.2.5. *Peninsular Rivers System*

1.2.5.1. The nature of the flood problem in the Peninsula is, naturally enough, governed by the topography. The Peninsula is essentially a high plateau, with rivers flowing between high banks. The chief west-flowing rivers are the Narmada and the Tapi. They do not have serious flood problems. Only, some inundation is caused here and there. In the category of the Peninsular rivers, by far the most important, are the Mahanadi, the Brahmani, the Baitarni and the Subarnarekha in Orissa, and the Godavari and the Krishna in Andhra.

1.2.5.2. The major rivers of Orissa split up into several branches in their deltaic stage. When they reach their deltas, they pass through highly populated coastal districts of the State to the sea. Heavy precipitations over the catchment areas lead to swirling waters overflowing the banks of these rivers. As far as the Mahanadi basin is concerned, by and large, considerable protection will be assured to the delta because of the construction of the dam at Hirakud. Among the major rivers which deserve attention in Orissa at present are the Brahmani and the Baitarni. Relatively speaking, the Subarnarekha has less serious problems.

1.2.5.3. In addition to these major rivers, there are numerous coastal streams in Orissa which, in the aggregate, cause considerable havoc. The deltaic area from the Chilka lake in the south to the Bengal border in the north suffers every year to some extent from floods in one or more of these rivers. Another factor which complicates the problem is the littoral drift of the sea along the Orissa coast. This tends to silt up the mouths of these rivers and causes flooding in the lower reaches. Worse conditions result when heavy rainfall occurs simultaneously in more than one of the catchments of these rivers as this produces synchronous floods over the entire delta which can be further aggravated by the prevalence of high tides at the sea at the same time.

1.2.5.4. The major rivers of Andhra—the Godavari and the Krishna—also exhibit similar problems in the delta. Embankments have, however, been

constructed there along these rivers and if properly maintained and further extended where necessary these should afford considerable protection.

1.2.5.5. Like Orissa, Andhra has also numerous coastal streams which collectively cause much damage. In the monsoon season, local heavy precipitation causes serious floods. The catchment areas of these rivers, being in the Eastern Ghats, are generally hilly and narrow. Flood control schemes on these streams would provide protection to valuable deltaic and upland areas from submersion. By far the most important coastal problem is presented by the Kolleru lake and the numerous rivers that rise in the Ghats and flow into the lake. Rivers like the Budameru and the Thammileru not only overflow their banks along their course to the Kolleru lake but also cause a rise in the lake level resulting in much inundation of the marginal land.

1.3. Difference in the Nature of the Problem in the Himalayan and Non-Himalayan Rivers

1.3.1. The excessive sediment load in the Himalayan rivers is attributable to the fact that these rivers drain geologically unstable hill formations and the alluvial plains. This is further aggravated by high seismicity along the Himalayan mountain ranges resulting in numerous and heavy landslides. Rivers in Deccan, either flowing from the Vindhyan plateau into the Arabian Sea, like the Narmada and the Tapi or those rising in the Western Ghats and flowing into the Bay of Bengal, like the Godavari, the Krishna and the Kaveri, flow in relatively stabler geological formations and carry less silt. The lower rainfall intensity in the regions they traverse, and the smaller range in temperature variations are additional factors responsible for the lower sediment load. Another distinguishing feature between the Himalayan rivers and those in the Peninsula is that while the fromer are snow-fed and hence perennial, the latter are purely rain-fed and hence periodical, flowing mostly in the monsoon period. Such of the river flow as is seen in the mouths of these rivers in the non-monsoon period, is chiefly derived from substratum regeneration.

1.3.2. These distinguishing features create differences in the types of flood problems met with. The Peninsular rivers do flood, but not as frequently as the Himalayan rivers. Moreover, bank erosion, meander and other characteristics associated with sediment are generally absent in them. Flooding in the Peninsular rivers is very often due to flow over natural banks as a result of concentrated heavy downpour of rain.

1.4. The Relative Seriousness of the Problem

1.4.1. In assessing the relative seriousness of the problem, it is difficult to evolve a common yardstick for comparison. Each river poses its own problems

to the local inhabitants, for whom it is a matter of life and death. The mere magnitude of the flood peak is quite an inadequate criterion for assessing the intensity of the flood problem. A discharge of 10 lakh cusecs is a serious thing for the upper Brahmaputra valley, whereas a discharge of only 80,000 cusecs causes havoc in the Jhelum valley in Kashmir. A discharge of 10 lakh cusecs in the lower Krishna may cause serious damage to the Krishna basin, whereas a discharge of only 20,000 cusecs in the Budameru river in its close vicinity causes considerable human suffering. Even so, frequency of flooding and the extent of damage done year after year are likely to convey a broad idea of the relative seriousness of the problem.

1.4.2. Judged by those criteria, it would be found that the flood problem is more serious in the eastern parts of the country than in the western; it is more serious in the northern part of the country than in the southern. It will not be a hazardous venture to make a generalization of the type that the seriousness of the flood problem increases from West to East and from South to North in the country as a whole.

1.5. The Ultimate Scope of Flood Protection

1.5.1. A moment's reflection on the ultimate nature of the flood problem will not be out of context. It will be worthwhile to recall the statement of the Union Minister for Irrigation and Power made on 27th July, 1956 in the Lok Sabha, wherein he stated that "absolute immunity from flood damage is not physically possible even in the distant future, because of the unpredictability of the several natural forces which might cause unprecedented situations. Even so, the good, though modest, beginning made in this country lends enough reason to look forward to an appreciable diminution in human distress with the implementation of the programme planned". It is against this background that aspects like flood plain zoning, flood forecasting and warning, flood insurance and measures of the like assume as great an importance as physical works directed towards mitigating the flood damage within economically justifiable limits.

CHAPTER II

A Brief Resume of Past Efforts in Flood Control

2.1. The problem of flood control is nothing new to India. As in several other countries in the world, almost every river in India has swollen up, at one time or the other, beyond its usual limits and caused considerable damage.

2.2. Embankments

2.2.1. The earliest efforts were left entirely to private individuals who put up embankments for the protection of specific localities in the flood affected areas. In course of time, this individual activity led to an unplanned and haphazard construction of embankments along the river banks and elsewhere. Not being scientifically planned, the embankments suffered several breaches. The inadequacy of individual effort in the sphere of flood control led to governmental interest in the problem, chiefly during the past century. As a result of this, a number of well-planned embankments have been constructed on some of the rivers which were causing recurrent flood damage.

2.2.2. The more important of such embankments constructed in Bihar and Bengal prior to the First Five Year Plan were about 100 miles along either bank of the Gandak, 75 miles along the Damodar and 2,200 miles in Sunderbans area.

2.2.3. In Orissa all the major rivers, *i.e.* the Mahanadi, the Brahmani, and the Baitarni were embanked in their coastal reaches for a total length of 1,029 miles—751 miles along the Mahanadi, 178 miles along the Brahmani and 100 miles along the Baitarni.

2.2.4. In South India, the Godavari and the Krishna were embanked in their deltaic reaches on both sides for about 80 miles and 75 miles respectively. The Kaveri has also flood banks in its lower reaches.

2.3. Reservoirs

2.3.1. No reservoirs were constructed in the past only for purposes of flood control. A large number of tanks, more particularly in South India, were, however, constructed for irrigation and drinking purposes. For example, there are about 8,000 tanks in Andhra, 35,000 in Mysore State and a large number

in Madras. These tanks though individually small, collectively afford considerable moderation in flood peaks during the earlier part of the monsoon season.

2.3.2. During the last two to three decades, the construction of reservoirs for flood protection, among other needs, has also been receiving active consideration. For instance, flood protection is one of the primary purposes of the Hirakud reservoir on the Mahanadi in Orissa and the reservoir system planned on the tributaries of the Damodar in Bengal.

2.4. Conferences and Committees

2.4.1. In addition to such physical efforts to control floods or to minimise the resulting damage, a number of conferences were held from time to time in the various States, some under official auspices and others non-official, to consider the problem in a comprehensive manner. But the efforts have, until very recent times, been confined to a few States. In some cases, regional flood committees were formed which made a number of valuable recommendations.

2.4.2. A list of reports submitted by such committees is given at Appendix A. The recommendations made by the committees, the extent to which they have been implemented and those which still hold the field, are discussed in Volume II of this Report.

2.4.3. By and large, the recommendations made by the various committees, excluding those that have a bearing on specific problems in their respective jurisdictions, may be summarised as under :

(i) Greater attention to be paid to the work of collection of essential data;

(ii) Separate staff to be posted for the collection of data needed for a study of the flood problem with a view to suggest remedial measures;

(iii) Increasing the waterway in rail and road bridges where inadequate;

(iv) Improving the drainage of low lying areas and providing outlets in continuous canal, rail or road embankments;

(v) Constructing flood control reservoirs;

(vi) Constructing marginal bunds;

(vii) Constructing diversion channels;

(viii) Soil conservation and land management measures in relation to flood control;

(ix) Instituting an adequate system of flood warning;

(x) Model experiments for some of the reaches of the problem rivers.

2.4.4. Among the various recommendations listed above, past efforts were primarily confined to the construction of embankments and a consideration

of the possibility of creating reservoirs. In respect of soil conservation, some efforts have been made in the Sivalik hills in the Punjab. The rest of the recommendations were not acted upon for a variety of reasons like paucity of funds, shortage of staff, etc.

2.5. Recent Approach

2.5.1. The disastrous floods of 1954 altered the approach to the flood control problem in the country. Just as in the past when State Governments had to take interest in the problem because it was beyond resources of individuals, so now it is being increasingly realised that effective flood control measures require a national effort and direction.

2.5.2. The work entrusted to the High Level Committee on Floods constitutes the first attempt in the country for a national review of the problem.

CHAPTER III

Flood Damage in India

3.1. Abstract of Flood Damage in the Country

3.1.1. The enormity of the flood damage in the country as a whole and in the different river basins and States is too well known to need any elaborate reiteration here. In discussing the nature of the flood problem in the country and in considering remedial measures, it will not be out of place to briefly touch upon the extent of damage, in so far as it provides the necessary perspective for visualising the nature of the problem and the significance of the proposed remedial measures.

3.1.2. Available statistical data, culled from different sources, under different classified headings is presented in Tables 1—16 and in Figures 1—8.

3.1.3. In the country as a whole, the total damage from 1950 to 1956 has been of the order of Rs. 323 crores, excluding the value of loss of cattle and human beings, and loss due to breakdowns in transport, industry, etc. Out of this, crop damage accounts for Rs. 228 crores, damage to houses and property for Rs. 74 crores and damage to public utilities for Rs. 21 crores (Table 3).

3.1.4. In addition to direct damage, expenditure on relief and rehabilitation during the same period of 1950-56 has been of the order of Rs. 56 crores (Table 12). Thus, during the last seven years, the total flood loss including the damage and relief, cost the country about Rs. 379 crores. The total direct damage including relief expenditure on account of 1955 floods alone was of the order of Rs. 146 crores (Table 12).

3.1.5. The Central Water and Power Commission estimate that taking into account indirect losses also the annual national income would go up by about Rs. 100 crores, if there were no flood damage in the country. On an average, we are losing over Rs. 46 crores annually by way of physical destruction of property and are incurring an expenditure of Rs. 8 crores on relief and rehabilitation of flood victims.

3.1.6. It should be realised, that this statistical sum-up is based on very inadequate data which are incomplete in a number of ways. Therefore, the

annual loss to the country is, perhaps, much more than what is indicated above.

3.1.7. Among the different States, U.P. is the worst affected State in point of total damage in the country, followed in order by Bihar, the Punjab and Assam. U.P. accounts for 33 per cent, Bihar 27 per cent, the Punjab 15 per cent and Assam 12 per cent. Thus these four States account for 87 per cent of the total damage in the country (Table 2).

3.1.8. Available statistics show (Table 2, Col. 3) that the Punjab suffers more than Assam or even West Bengal, contrary to prevailing impressions. The damage in the small Union territory of Delhi is much bigger than that in Madhya Pradesh. The flood damage in Rajasthan is almost as severe as in Tripura, a statement which again would run contrary to common belief.

3.1.9. For judging the extent of damage from different criteria, damage per capita and per acre of area sown is tabulated in Table 4. It will be seen that the annual per capita flood damage is the heaviest in Assam, being of the order of Rs. 6. The annual damage per acre of net area sown is also the highest in Assam being of the order of Rs. 7. No such single index, however, is an adequate indication of the urgency of the flood problem or its importance in any particular area. Perhaps, the total damage including loss of land revenue and expenditure on relief in different areas would furnish a reasonable yardstick for apportioning remedial resources, allowance being made for any emergencies or overriding priorities.

3.1.10. Referring to floods in the U.S.A., Hoyt and Langbein* remark that "figures of damage are not large compared with the whole of the nation's output of goods and services. They are not even large compared with our national budget. They are not larger than losses from fire and are but a fraction of the losses caused by insects and rodents on the farm. Averages can be misleading. Flood damage comes in heavy, bitter doses. It occurs suddenly, quickly, over a relatively small section. In years with large floods the damage is several times the mean. Moreover, the full load of a flood is borne by comparatively few communities". This statement intended for the U.S.A. is equally true for India.

3.2. Basinwise Assessment of Damage

3.2.1. As almost all the information on damage is available Statewise, it is difficult to split it up exactly into the individual river basins. An attempt has, however, been made in Tables 12 to 16 on the following basis. The Ganga

*Floods by William G. Hoyt and Walter B. Langbein 1955, Princeton University Press, page 77.

system includes figures for the States of Delhi, Uttar Pradesh, Bihar and West Bengal. The entire damage in West Bengal in 1956 occurred in the central, western and southern districts which lie in the Ganga basin. Therefore, figures for 1956 have been accounted for in the Ganga system and for the period 1950-55 in the Brahmaputra system, the damage being in North Bengal. The Brahmaputra system includes the States of West Bengal (from 1950 to 1955) and Assam. The North-Western Rivers system includes the States of the Punjab, Jammu & Kashmir and Himachal Pradesh. The other river systems include the States of Andhra, Orissa, etc.

3.2.2. It will be seen from Table 12 that by far the greatest damage in the country occurred in the Ganga system *viz.*, Rs. 203 crores out of the total damage of Rs. 323 crores during 1950-56, that is as much as 63%. Next in magnitude was the Brahmaputra system which accounted for 16% of the total damage. The North-Western rivers followed closely, the percentage being 15, while the remaining river systems together aggregated to 6% of the total damage.

3.2.3. It would be interesting to study the variation in the incidence of annual damage in the different river basins. In the Ganga system the maximum annual damage in recent years occurred in 1955, being about 30%, the damage in 1953 being 24% and that in 1956, 21%. In the Brahmaputra system, 54% of the total damage during the period of 7 years occurred in 1954 alone, while in other years it ranged from 2% to 12%. In the North-Western Rivers system the 1955 floods were most disastrous. That year, the damage caused was 96% of the total for seven years (Table 15). In the other river systems, the damage in 1955 was 57% of the seven-year total. It would thus be seen that the annual variation in damage is pronounced in the North-Western Rivers system and the Brahmaputra River system. In the Ganga system, the variation is comparatively less marked.

3.2.4. The distribution of damage in those four river systems under three classified heads, *viz.*, crops, houses and public properties, has been shown in Figures 5 to 8 and Tables 13 to 16, from which it will be seen that the crop damage was maximum; its proportion to the total damage in the basin being 78% in the Ganga, 65% in the Brahmaputra, 45% in the North-Western rivers and 72% in other river systems. Damage to houses was maximum in the North-Western Rivers system, amounting to 47%, while in others it varied from 18 to 21 per cent. Damage to public properties was least in the Ganga basin, being 4%, while it was maximum in the Brahmaputra, being 14%.

3.3. Is the Flood Damage Increasing ?

3.3.1. It would be interesting to see if there has been a steady increase in the flood damage. There is also the question, whether there has been any

increase in flood intensities in recent years. Figure 3 shows the yearly incidence of total flood damage and crop damage in India during the last seven years, 1950-1956, and Figures 5—8 show the corresponding data for the different river basins.

3.3.2. A damage of about Rs. 21 crores in 1950 increased to Rs. 51 crores in 1953, Rs. 58 crores in 1954 and Rs. 126 crores in 1955. The damage however fell to Rs. 51 crores in 1956. A similar trend is indicated in respect of the total crop damage in India and also in the corresponding damage data in individual river basins (Figs. 5—8).

3.3.3. It would, however, be incorrect to draw an inference that the damage has been increasing in recent years, because available data are too meagre to warrant such a conclusion; nor can any inference be drawn on the increasing flood damage on the same analogy as increase in flood intensities, which will be discussed in Chapter IX, because the maximum flood intensity, although bearing a relation to flood damage, is not an adequate pointer to the proportionate extent of damage. The time of occurrence, the duration and frequency are other aspects which govern the extent of damage.

3.4. The Importance of Crop Damage

3.4.1. The distribution of total damage in India under various classified heads is shown in Figure 2. By far, the heaviest damage is in relation to agricultural crops. Next in importance comes the damage to urban and rural property, the damage to public utilities ranking third.

3.4.2. Table 3 illustrates the damage in different years. In 1950, 75 per cent of the total damage was crop damage and the corresponding figures for the succeeding years were 69, 37, 80, 72, 64 and 80 per cent in the years between 1951 and 1956. It is interesting to note the variation in the relationship between the crop damage and the damage to houses in columns 3 and 5 of Table 3. In 1952, the damage to houses was higher than the damage to crops whereas in the other years it has been consistently less, the proportion varying from the minimum of 5·43 in 1953 to the maximum of 2·75 in 1951.

3.4.3. Similarly, the extent of damage to public utilities has been varying. The year 1952 shows the heaviest percentage of damage near about 18 per cent whereas in the other years it has been about 7 per cent (Table 3, Col. 8).

3.5. Inadequacy of Existing Data

3.5.1. The fundamental need in the matter of flood damage data is to induce more realism in the different estimates, as the reliability of the reported figures

has not been beyond question. The techniques of damage assessment in different States are not known. In the absence of uniform assessment techniques, the reported data are, strictly speaking, incomparable. Moreover, the damage in 1956 is not comparable to the damage in 1951 even inside a State because of the changing price levels. In comparing annual damage either in the same State or among different States, allowances will have to be made for increases necessitated by increased prices, increased property values and farming costs. In the absence of such comparable standards in assessment, it will be difficult to decide how far to go by a reported excess damage in one State over another. The need for standardization and uniformity in measurement techniques and reporting has been debated and generally accepted by various flood control organizations like the State Technical Committees, River Commissions and even the Central Flood Control Board. But, by and large, we feel that the requisite precision in these techniques of measurement have not improved materially and even today the position is not very different from that in 1950. There has been a greater desire for the collection of this data under different classified heads but there has not been a proportionate improvement in the assessing and reporting techniques.

3.6. The Engineering Significance of Flood Damage Data

3.6.1. The collection of damage data has to be looked upon from two different aspects; firstly, the administrative and the economic aspect and secondly the engineering aspect. The former centres round the need for constant vigil for removal of acute distress either during floods or immediately after their occurrence. It is a part of the welfare functions of the Government. It also includes the determination of deservedness of affected areas for sanction of remission of revenue, organization of relief, and rehabilitating the people from the areas threatened by floods. This aspect does not fall within the purview of the Ministry of Irrigation and Power. It is the engineering aspect that does so and this pertains to the economic justification for undertaking an engineering measure or in formulating a flood control scheme or schemes at a particular cost. The flood control benefits can be divided into two categories, namely, direct and indirect. The indirect benefits can again be divided into two categories, namely, the tangible and the intangible. It is not necessary in the present context to enter into the details of the techniques of measurement of damage in these various categories. Whatever be the techniques, if a flood control scheme is proposed, it is necessary to assess the total benefits which are likely to accrue to the beneficiaries, convert them into a monetary value and compare it with the cost. For this kind of economic analysis, it is not necessary to collect daily and weekly information about the damage under different heads. It is enough, if we have a picture of the annual damage for a number of years in the area proposed to be protected by individual schemes.

3.7. Future Collection of Flood Damage Data

3.7.1. At its sixth meeting held on 22nd August, 1957, the Central Flood Control Board decided that the work of collecting information in respect of flood damage should be divided into two parts, the one relating to the engineering aspect, information on which should be supplied by the State engineers, and the other relating to the non-engineering aspects, information on which should be collected by the Ministry of Home Affairs and the Ministry of Food and Agriculture through their own channels. The intention seems to have been that information in respect of damage to engineering works concerning the Ministry of Irrigation and Power would get reported to that Ministry, and that damage to other engineering works, such as, roads, railways, etc., would get reported to the respective Ministries. Likewise, damage to crops, habitations, loss of life, etc. will get reported to the Ministries concerned. The Ministry of Home Affairs would receive information from the various Ministries and the State authorities for a final compilation of the overall flood damage data.

3.7.2. The main utility of these data when collected, apart from any immediate administrative purpose, is to enable the engineer to make a realistic assessment of cost-benefit ratio of the flood control schemes which he may prepare. Sanction of flood control schemes has to depend in main on their economic justification. It is, therefore, important that the data which are collected in the various States are depicted in forms which are of ready and adequate utility to the engineer. It is also important that the agencies in the various States responsible for collecting the data, do so on a uniform standard of assessment, and in prescribed forms. It is recommended that the Ministry of Home Affairs may issue instructions to the State authorities, prescribing standards of assessing damage and laying down proformas. These latter might be prepared in consultation with the Ministries concerned so that these give information in a form which would meet their requirements.

3.7.3. As has been stated above, the data of flood damage has to be utilised in assessing the justification of the various flood control schemes. It is important that in the States the flood control department is furnished with all the information in respect of flood damage collected by other departments. At the Centre, likewise, all the flood damage information should be made available to the Central Water and Power Commission who have the responsibility of examining and recommending the various flood control schemes sponsored in the States. It would perhaps be most convenient and suitable if the State Governments while sending information in respect of flood damage to the various Ministries of the Central Government send a copy to the Central Water and Power Commission also.

CHAPTER IV

The Place of Flood Control in Five-Year Plans

4.1. Flood Control in the First Five Year Plan

4.1.1. The Planning Commission published in May 1957 a "Review of the First Five Year Plan". According to this review, "When the First Five Year Plan was drawn up, schemes directed towards flood control were dealt with broadly as part of the irrigation programme. The floods of 1954 and 1955, which caused damage in several States, led to the building up of organizations for undertaking flood control measures".

4.1.2. After giving details of the establishment of the Central Flood Control Board, the River Commissions and the State Flood Control Boards, the Review gives details of the financial targets achieved. "During the last two years of the First Five Year Plan, the total expenditure on flood control works, which were specially approved, was of the order of Rs. 10·8 crores." Then follows in the Plan Review a brief account of the schemes undertaken in the various States like Assam, Bihar, U.P., West Bengal, Jammu & Kashmir, Punjab, Delhi and Orissa.

4.1.3. The only mention of flood control in the First Five Year Plan published in 1952 is as follows :—

> "Although flood control cannot be called a water use, the problem of flood control can best be considered in relation to the existing development on the rivers in India. Every year considerable damage occurs from floods in different parts of the country. Until recently, no regular statistics of this damage were collected. Whenever heavy damage resulted from a flood in the larger rivers, enquiry committees were set up and in some cases suitable flood control measures were undertaken. Extensive embankments have been constructed in parts of Assam, Bihar, West Bengal and Orissa. The problem of flood control is now always considered in conjunction with the construction of multi-purpose projects. The construction of large dams to store these flood waters is the most effective way of preventing flood damage." **(Page 339 of the First Five Year Plan)**

4.1.4. It is significant to note the last sentence of the above paragraph wherein it is stated that the construction of large dams to store the flood waters is the most effective way of preventing flood damage.

4.1.5. While the construction of reservoirs is undoubtedly an effective way of minimising flood damage, this enunciation in itself did not adequately serve the needs of policy formulation in the field of flood control. The inadequacy was, however, underlined by the floods of 1954, whereafter the national flood control policy was announced by the Government in three phases, namely, the immediate, the short-term and the long-term. The works contemplated in these three phases are given below, extracted from the statement of the Union Minister for Irrigation and Power placed on the Table of the Parliament on September 3, 1954.

"(i) *Immediate.*—The first phase will extend over a period of two years. This period will be devoted to intensive investigation and collection of data. Comprehensive plans will also be drawn up and designs and estimates prepared for short-term measures of flood protection.

Some measures such as revetments, construction of spurs and even embankments may be adopted immediately at selected sites.

(ii) *Short-term.*—During the second phase, which may be taken to start with the second year and extend to the sixth or the seventh year, flood control measures such as embankments and channel improvements will be undertaken. This type of protection will be applicable to a major portion of the areas now subject to floods.

(iii) *Long-term.*—The third phase will relate to selected long-term measures such as the construction of storage reservoirs on tributaries of certain rivers and additional embankments wherever necessary. This may take 3 to 5 years."

4.2. Flood Control in the Second Five Year Plan

4.2.1. *Policy*

4.2.1.1. The elaboration of the flood control policy in the current Plan is contained in the Report of the Second Five Year Plan.

"While both direct and indirect benefits of flood control works are considerable, it should be mentioned that such works may, in certain

conditions, have adverse effects by depriving inundated areas of silt which has considerable fertilising value. The principal benefits of flood control are in the greater economic security and continuous development which they ensure. It is impracticable to provide complete protection against floods. Even if this were technically possible, the cost would be prohibitive. Flood control works selected for a region have, therefore, to be such as will conform to the local conditions and afford appreciable protection at reasonable cost."

4.2.1.2. The Plan also recommends a consideration of the various methods available for flood control to reduce the damage and intensity of floods and recommends the preparation of comprehensive river basin plans. It also recognises that the preparation of a balanced scheme for a river basin is a complex engineering, economic and social problem. It goes on to assert that it is of primary importance that surveys should be completed and necessary data collected to formulate appropriate flood control proposals expeditiously. Until this is done, the Plan recommends that only protective works of immediate nature should be carried out which will eventually form a comprehensive plan. The Committee emphasise the urgency and importance of completing investigations, and of the preparation of comprehensive basinwise flood control plans.

4.2.2. *Financial Allocations*

4.2.2.1. A draft plan for flood control projects, published by the Ministry of Irrigation and Power in August 1950, provided for an expenditure of Rs. 117 crores, including schemes continuing from the First Plan and that on the embankment portions of the Kosi Project. Since the preparation of the draft plan, the question regarding the provision to be made for the flood control programme was further examined by the Planning Commission and the Ministry of Irrigation and Power in the context of the limited resources available for the Second Plan *vis-a-vis* the pressing demands of other sectors. As a result, the Plan provision has been reduced from Rs. 117 crores to Rs. 60 crores.

4.2.2.2. The statement of the Union Minister laid on the Table of the Lok Sabha on 27th July, 1956 lays down the following policy in the matter of utilisation of the Plan provision:—

"The annual programme of expenditure in the Second Five Year Plan period will not be treated as inflexible. It is the Government's intention that once schemes have been finalised, all possible measures should be taken to execute them as far as possible, even

if it involves more expenditure in the earlier years. This will ensure earlier realisation of benefits and a consequent increase in human welfare and national wealth."

4.3. A Few Aspects of Policy

4.3.1. We would like to briefly touch upon a few aspects having a bearing on these problems for the consideration of the Ministry of Irrigation and Power, Central Water and Power Commission and the Planning Commission.

4.3.2. *Flood Control Aspect to Retain its Importance in Multi-purpose Projects*

4.3.2.1. Many multi-purpose schemes originated because of the acute flood problems in those areas. In fact some of the biggest schemes in the country now, like the D.V.C., the Hirakud and the Kosi, were originally conceived to combat floods and mitigate the flood damage. Other water uses like irrigation and power were introduced into the schemes, in the interest of multiple development of water resources in the regions and making the schemes more productive and economical. The Tennessee Valley Authority is a famous instance outside the country.

4.3.2.2. Flood control benefits being primarily of an indirect nature and varying from year to year are apt to lose their importance *vis-a-vis* the more direct and more steady benefits such as power generation and irrigation. In multi-purpose projects, care should be taken to ensure that the flood control aspect is not allowed to lose its importance. For instance, in the operational stage the temptation has to be resisted to sacrifice the interests of flood control in favour of other benefits like power and irrigation.

4.3.3. *More Precise Measurement of Benefits Required*

4.3.3.1. The measurement of benefits of flood control projects included in the successive plans has so far remained more qualitative than quantitative. In several embankments schemes, the benefit is described as the protection of a certain acreage. To say that a particular embankment scheme would protect a given area or that a spur or a revetment would arrest erosion for the benefit of a particular town, true as it is, will not be an adequate description to facilitate a comparison of the benefits during the plan period both physical as well as monetary, with the ultimate possible benefits in the region or the basin. A certain group of schemes in a river basin included in a five-year plan will together make possible a certain magnitude of benefit. This should be compared with the ultimate flood protection targets in the basin, to give an idea of how far the fulfilment of the flood control portion in the plan would lead us nearer the ultimate goal.

Such a comparison would only be possible if ultimate physical targets of benefits are known and the progress achieved from one five-year plan period to another is estimated in as precise a manner as possible, subject to the usual well-known limitations involved in such computations. At any rate, we feel that there is a greater need for a more precise quantitative assessment of benefits of flood control projects which might be included in the future five-year plans. We recommend that the actual techniques of such measurement or assessment be evolved for adoption by the States.

4.3.4. *Inter-relation with other Water Development Schemes*

4.3.4.1. The relation of flood control schemes with other water development schemes is pertinent to be considered in the context of examining the role of flood control in the five-year plans. A scrutiny of the several works included in the Second Plan reveals that the provision of Rs. 60 crores includes Rs. 9 crores for the Kosi Project and Rs. 3.16 crores for the D. V. C. Excepting for these two projects namely the Kosi and the D. V. C., the cost of various other multi-purpose projects allocable to flood control is not shown in the details of the flood control provision.

4.3.4.2. There has also been a directive by the Planning Commission that no multi-purpose schemes are to be included in the flood control sector, unless financial provision for such schemes exists under other sectors. In accordance with this directive, schemes proposed by certain State Governments like Andhra and the Punjab involving the construction of storage reservoirs were disallowed in the flood control sector of the current Plan because there was no provision for them in the irrigation or power sectors. These reservoirs schemes, being essentially flood control schemes, were not put forward for the consideration of the Planning Commission earlier when the programmes of different States were discussed in the irrigation and/or power sectors. The flood control sector was considered separately and, to a certain extent, in isolation from the other two sectors. Therefore, these schemes were dropped because there was no corresponding provision in the irrigation or power sector.

4.3.4.3. The Committee would recommend that, in future, a simultaneous discussion of the irrigation, power and flood control sectors in a basin is more conducive to a closer integration of these three aspects. Moreover, when these aspects are thus discussed together, it would be salutary to follow the principle that, in the case of multi-purpose projects, financial provision should exist in all the three sectors of the plan and if it does not exist in one, it need not find a place in the others.

CHAPTER V

Embankments as a Method of Flood Protection

5.1. Embankments—the Earliest Method of Flood Control

5.1.1. The building of embankments as a means of protection against flood waters, being the direct, the cheapest and immediately effective method has dated back from the earliest recorded history. In Egypt, Amenemhat of the twelfth dynasty built dykes on both banks of the Nile for the protection of cultivated lands. The city of Babylon was protected by a system of levees. In China, the great levee system on the Yellow river appears to have been started before the seventh century B.C. At first, isolated sections of dykes were built to afford local protection, but the continuous system of dykes along both banks of the river commenced in 69 A.D. on the Yangtze river; these were constructed later in the sixth century and those on the Pearl river in the beginning of the twelfth century. Thus this method of flood control has been pursued extensively through centuries in that country, and now 56 per cent of the total arable area of the 22 provinces of China and nearly half the population of that country is protected by dykes. In Japan, with its high intensity of population, dykes have been and are still being used as the principal means of flood control. The Po in Italy has an early record of embankments which have successfully served their purpose. On the Mississippi, the earliest system of levees to protect the city of New Orleans, was completed in 1727. Since then dykes have been constructed on this river along the various reaches till today and practically the entire river is dyked.

5.1.2. In India dykes have been in use for thousands of years for protection against floods, particularly in delta areas. Most rivers flowing through alluvial plains have protective dykes in some reach or the other; the notable rivers having extensive embankments being the Gandak, the Damodar, the Mahanadi, the Godavari, the Krishna and the Kaveri. Recently extensive dykes have been built on the Brahmaputra, the Burhi Gandak and several other rivers.

5.2. Earlier Dykes—Private Venture

5.2.1. The earlier dykes in practically all countries, were more or less individual or private ventures, built piecemeal and extended gradually. No great system of dykes was ever completed in one attempt. Embankments

have been in existence in the delta areas of the Godavari, the Krishna and the Kaveri for centuries. In Orissa flood embankments appear to have existed from very early times, mostly in isolated places to protect small areas. These were maintained by zamindars under the Marhatta Government and their maintenance was taken over by Public Works Department between 1831 and 1855. In Bengal, the maintenance of Damodar embankments was taken over by Government in 1788. In Bihar, embankments have been in existence on the Gandak for about a century now. The now defunct Birbund on the Kosi was built centuries back.

5.2.2. In olden days the maintenance of embankments, being the responsibility of private individuals or local authorities, was seldom satisfactory. Therefore, in course of time this had to be taken over by Governments. Most of these early dykes the world over had been built to inadequate section and had been strengthened subsequently as failures occurred and the need for strengthening became apparent. Likewise, these earlier dykes had insufficient freeboard, being based on inadequate record of flood heights. The floods invariably exceeded past heights resulting in overtopping of the embankment and causing its failure.

5.3. Controversy Regarding Embankments

5.3.1. The suitability and effectiveness of embankments as a measure of flood control has been a matter of controversy since long ago and in many countries. Depending upon the behaviour of the different rivers in their various reaches, influenced by silt intensities and silt grade, discharge, bed slope, effect of tides if any, etc., experience in respect of embankments has differed. Every time any disastrous breaches occurred following very high floods, opinion sharply went against construction of embankments, later to gradually veer round in their favour with dimming of memories of distress and losses which had resulted from failure of embankments.

5.3.2. In India, opinions have differed not only from State to State, but also have changed from time to time. Also there has been a conspicuous vacillation of opinions in certain States, notably Bihar and Orissa. For the past few decades the **Bengal** engineers have expressed themselves against embankments, but this hostility to embankments has got somewhat modified in recent years. The opinion of the Bengal engineers seems to have been greatly influencing the decisions taken not only in the neighbouring States of Bihar and Orissa but also those in Burma, where construction and strengthening of embankments got discouraged and proposals got advanced to remove some of those already constructed. On the Damodar which had embankments

on both banks dating earlier than 1788, when their maintenance was taken over by Government, the right embankment was abandoned towards the middle of the last century. Realising particularly the evil effects of premature reclamation of land in the delta by embankments, the Bengal Embankments Act of 1873 was passed containing an important provision which made it a criminal offence to construct embankments without previous permission in certain areas declared as prohibited from time to time. The late Shri S. C. Majumdar, a former Chief Engineer of Bengal and an erstwhile Member of the Central Waterways, Irrigation and Navigation Commission, has dealt with the flood problems of Bengal in his paper "River Problems in Bengal" and has made a strong plea against embankments.

5.3.3.1. Embankments have been a subject of discussion in **Orissa** perhaps more than in any other State. Also in this State opinion has been changing from time to time. It would, therefore, be profitable to take note of the various events and the numerous deliberations which have been made there in respect of embankments. As has been stated earlier, the Public Works Department took over the maintenance of the existing embankments between 1831 and 1855. These embankments were improved but no additions were made during that period. During the high flood of 1855 and those of three preceding years a very large number of breaches occurred. During the period 1855 and 1881, with the construction of Orissa Canal system, there were 255 miles of canal banks serving as flood protective embankments, 510 miles of government flood embankments and 248 miles of zamindari bunds. These latter private embankments were of insufficient height and strength to withstand heavy floods and fell into disrepair and became useless. In 1896-97 an examination was made to maintain only those embankments which were considered actually useful or at least harmless and to abandon the rest. Many miles of embankments were abandoned and only 471 miles of embankments along large rivers and 265 miles of canals were continued to be maintained.

5.3.3.2. In November 1927, a Flood Committee of Engineers was appointed to investigate flood problems in Orissa. This Committee which submitted its report in August 1928 recommended that in areas which were not served by canal irrigation, all obstacles which militated against the free passage of flood to the sea should be removed as quickly as possible to the extent compatible with the maintenance of the population. The Committee was opposed to the erection of new embankments except in exceptional cases. The Committee recommended that private reclamation along the coast should be prohibited. For practical reasons, the policy of gradual removal of all embankments was not greatly favoured by the then Government. It might be mentioned here that on the Mississippi the 1927 floods proved disastrous and that was attributed

by people to double embanking of the river. This perhaps had influenced opinion in India as in certain other countries.

5.3.3.3. In 1937, Shri M. Visveswaraya reviewed the report of the 1928 Flood Committee. He laid stress on investigations and collection of data. He stated that "the object of the remedial measures for the protection of flood afflicted area should be to train the rivers on their way to sea by constructing protective embankments, judicious dredging, flood escapes, etc., by removing obstacles to floods, opening out estuaries and making cuts through sand banks, etc". He also desired the feasibility of constructing storage reservoirs on the rivers examined more fully, not being convinced by the assertion of the 1928 Flood Committee that those were not practicable. He further recommended the setting up of Flood Advisory Committee of three eminent engineers to supervise the technical side of the work and to maintain a continuous study of flood problems.

5.3.3.4. As recommended by Shri Visveswaraya, the Government of Orissa appointed a Flood Advisory Committee comprising Shri Rangaiya, retired Chief Engineer, Mysore, Sir Claude Inglis and the Chief Engineer, Orissa. This Committee functioning between 1938 and 1942 submitted a number of interim reports; the third interim report being submitted in 1942. This Committee was all in favour of embankments. The main recommendations of this Committee were briefly as follows :—

(i) To conserve and improve the main rivers by a system of adequate marginal embankments and by the provision or maintenance of efficient mouths to the sea so as to enable the rivers to carry their normal flood discharge ;

(ii) To prevent breaches, which lead to deterioration of the parent river ;

(iii) To spill water in excess of a pre-determined figure on to the land by high level escapes, so designed as to pass only the finer grade of silt ; and

(iv) To investigate the feasibility of multi-purpose reservoirs in river catchments and ensure against erosion caused by destruction of vegetation in the catchment areas.

5.3.3.5. The following additional points were made out by the Orissa Flood Advisory Committee :—

(a) To improve a river, it is necessary

(i) to improve the outfall conditions ;

(ii) to control the distribution of water and sand entry at the heads of channels ; and

(iii) to restrict the number of channels.

(b) Without double embankments, deltaic rivers break up and deteriorate. Double embanking in conjunction with the other measures recommended, retards or prevents such deterioration.

(c) Double embankments necessitate the provision of high level escapes. With the improvement of the river channels, the depth of spill through these escapes should be gradually reduced.

(d) Control by double embankments and escapes must be combined with suitable drainage of the basins between rivers.

(e) In giving effect to this policy, it may be necessary in certain cases to carry out river training works, such as closing certain channels, developing others, constructing spurs to control the direction of flow and protecting river banks.

5.3.3.6. A Flood Conference consisting of officials only and presided over by Shri B. K. Gokhale, Adviser to the Governor, was held at Cuttack in 1945. This Conference accepted the Orissa Flood Advisory Committee's recommendations in respect of embankments, but felt that the ultimate solution of the flood problem lay in constructing multi-purpose reservoirs. Since then the Hirakud Project has been completed and there are at present a total of 1073 miles of embankments in the State.

5.3.4.1. In the twenties and thirties of the present century opinion in **Bihar** was also against embankments. This appears to have been an echo of the opinion so forcefully expressed by Bengal engineers against the construction of embankments. About this time opinion in America was veering round to other methods of flood control, as after the floods of 1927 in the Mississippi the adequacy of protection by embankments became a matter of controversy. In 1937, a conference was held at Patna to consider the flood situation in North Bihar, with particular reference to the Kosi. At this conference Captain Hall, Chief Engineer, Bihar, made a strong plea against embankments and suggested that the existing embankments in North Bihar, which according to him had created a deplorable flood situation in North Bihar by impeding the free flow of flood waters, should be removed as far as possible.

5.3.4.2. On the Gandak, embankments on both banks have now existed for practically a century for a length of about a hundred miles from the outfall

of the river into the Ganga. These embankments have afforded very good protection to the area which prior to their construction used to get inundated almost every year. The embankments have not created any problem of siltation of the river bed.

5.3.4.3. In 1936, the Saran Flood Enquiry Committee recommended raising of some 35 miles of roads in Saran district by three feet above high flood level of 1926. The then Chief Engineer was not in favour of embankments, and in consequence this recommendation remained shelved. On the Ghagra there are seven zamindari embankments unconnected with each other, which have often been breaching.

5.3.4.4. Opinion in Bihar has lately veered round to embankments for protection against floods. On the Kosi the construction of embankments on both sides of the river to a total length of 160 miles got sanctioned in 1954, and major part of this programme has already been completed. The Burhi Gandak has since been embanked over major part of its length. Lot of other embankments have been built in the State.

5.3.5. In **U. P.** also opinion was sharply against embankments before the last Great War. At an Inter-Provincial Flood Conference held at Lucknow in January 1939, Pandit G. B. Pant, then Premier of U. P., who presided at this conference stated that in olden days the remedy of flood control was found in putting up embankments, and doubted if this was prudent or farsighted. The Technical Committee of this conference on which a number of senior engineers from U. P. and Bihar served, agreed that marginal embankments were found objectionable and were a contributory factor in raising flood levels. They, however, considered that isolated embankments for protecting towns, etc. were permissible. During the present decade, however, opinion in U. P. also had gradually been changing in favour of construction of embankments and a number of these have recently been constructed.

5.3.6.1. In **Assam** Shri S. C. Majumdar, Member, Central Waterways, Irrigation and Navigation Commission, examined the flood problems of the State in 1947. His views based on his experience in Bengal were against building of any embankments in the State. He stated that further extension of embankments should on no account be made. On the other hand the Government should seriously consider the desirability of removing the existing embankments. Till then there were not many embankments in the State. In fact, before the beginning of the First Five Year Plan there were only 43 miles of embankments in the whole of Assam. Shri Majumdar had recommended for consideration the construction of storage reservoirs.

5.3.6.2. Subsequent opinion in Assam has not been the same as that expressed by Shri Majumdar. During the last four years there has been great activity in the State in building embankments and now there are nearly 1400 miles of embankments in that State.

5.3.7. **Opinion in South India has,** by and large, been in favour of construction of embankments as a measure against floods. Embankments have now been in existence in the delta area of the Godavari, the Krishna and the **Kaveri for** a long time. No serious problems seem to have arisen in these areas as a result of construction of embankments there. Of course conditions on these rivers are different from those obtaining on the Ganga and its delta. For one thing, these rivers drain the Deccan plateau which is an older and stabler formation than the Himalayan area. The silt problem on the South Indian rivers is comparatively insignificant. Thousands of irrigation tanks in the Peninsula no doubt exercise a flood moderating and silt retention effect.

5.3.8. From the above paragraphs it will be noticed that opinion in India has differed on the matter of constructing embankments for flood protection. It has varied not only from State to State but also from time to time. The reason is that embankments, while they are suitable as a means of flood protection in certain situations, may not be suitable and desirable under other conditions. It, therefore, has to be examined under what conditions embankments are to be built and where they ought not to be built.

5.4. Experience of Embankments in Sind and Burma

5.4.1.1. The **Indus river**, both banks of which are now completely embanked from the northern border of Sind to the sea except where the ground is high, offers good material for study.

5.4.1.2. Prior to 1861, only some zamindari bunds existed on this river. These were improved and further bunds built from 1875 onwards. Whatever gaps remained were mostly closed during the construction of the Sukkur Barrage canals. The Sukkur Barrage itself was completed in 1932.

5.4.1.3. As in the case of the Ganga and the Brahmaputra, the Indus is an alluvial river which is gradually building up its bed on a flood plain of its own making so that the country slopes away from the river on both banks. Prior to the construction of embankments spill used to occur annually flooding large areas. A devastating flood occurred in 1861. That year two flood streams burst over Sind from the Indus. Water five miles in breadth and varying from five to three feet in depth swept across the country. It was in order to prevent this sort of situation repeating itself that embankments were built. In

1943, Sir Claude Inglis made an enquiry into the serious breaches in the Indus embankments that occurred in 1942. In his report he has stated that "it is significant to notice that the only clearcut rise in water levels which took place at Bukkur between 1848 and 1924 was some three feet between 1861 and 1882 most of which occurred in 10 years between 1872 and 1882. This rise synchronised with the period during which old river embankments were improved and new embankments constructed on both banks of the river above Sukkur. This, by stopping spill, caused a marked rise in water level and increased deposition on sand banks and berms—which, in turn, led to a further rise of water levels—but this rise was followed by a long period of slight improvement, during which new condition of flow between embankments became established". He concluded his report by stating that it was inevitable that river flood levels on the Indus would rise, and as they rise the danger of breaches and the damage resulting from breaches must increase. He was certain that in Sind an avulsion of the river would occur in no far distant date unless adequate steps were taken to prevent it.

5.4.1.4. Earlier in 1941, Foy made a study of regime level charges on the Indus system. In a paper published in 1941 he has pointed out that at Kotri, which is 134 miles above bifurcation of the Indus at the head of its delta, there had been a proved rise averaging 0.061 foot per year from 1863. His conclusion was that the dominant cause of the rise of regime level at Kotri was due to lengthening of the channel and that there had been no overall change in slope between Kotri and the sea.

5.4.1.5. In his paper Foy has quoted from an article in the 'Illustrated Weekly of India', dated 7th March, 1942 by Professor M. B. Pithawala, D. Sc., F. G. S., on the question of rise of levels on the Indus as under—

"Since silting is going on to an enormous extent in Sind, the level has been steadily rising with the deposit of silt year by year. This rise in level is also responsible to a very great extent for the instability of the river's course. It has been calculated that during the last 5,000 years, from the time of Mohenjodaro in fact, the rise of level is 50 feet, *i.e.*, one foot per century. This nearly tallies with the total depth of ruins reached by archaeologists like Sir John Marshall, and is sufficient to keep the river constantly unstable. As time goes on, it must swing from one side to another."

5.4.1.6. Embankments preclude land building activity outside the embankments. From what Sir Claude Inglis and Mr. Foy have brought out in their reports the dangers which the construction of embankments on the Indus, which is an aggrading river, has created for posterity are manifest.* However, it must be recognised that aggradation to some degree will also have occurred if no embankments had been constructed.

5.4.2.1. There were no dykes in the delta of **the Irrawaddy in Burma** until 1860. A dyke along the right (west) bank was projected in 1861. By 1883, a system of dykes at the head of the delta, stretching from the high ground above Kyangin to Pantanaw, a distance of 132 miles, was completed. Up to about 1920, dyking was accepted without opposition as the method of flood control. There were high floods in 1926 and considerable damage occurred. In America, the 1927 floods proved disastrous on the Mississippi, and this was attributed to double embanking of the river. This veered the opinion of engineers in Burma against embankments and the proposals to double embank the Irrawaddy got shelved. A large number of village embankments had, however, already been built and early in 1929 a wholesale strengthening and reconstruction of these was reported. Government prohibited further raising or new construction of village embankments, but some five lakh acres of land had already been opened up and cultivated under the protection of these village dykes, incomplete as they were. Mr. McIntosh, Chief Engineer, expressed the view that eventually it would be necessary to remove long stretches of the Yandoon and Thongwa embankments to silt up the interior, but doubted whether anything could be done to remove these embankments as he felt the land owners would not agree to be "drowned out" for the sake of future generations.

5.4.2.2. In August 1939, there occurred one of the biggest floods ever recorded on the Irrawaddy. Mr. England was appointed an officer on special duty to report on the situation. In his report submitted in 1940, he stated that storage or detention of flood waters in the head reaches of the river would not be economical. Providing escapes above the delta was considered equally impracticable, nor did he consider enlarging the river channel in the delta area feasible. He, therefore, recommended distribution of flood waters over as large an area as possible of the least developed parts and building up of the delta land by deposition of silt. For practical reasons the embankments already built had to be left intact but the general policy was to be towards removal of embankments if possible and not building further embankments in the delta.

5.4.2.3. Thus in Burma, protection by embankments alone has not been found dependable and adequate, and till storage or detention of flood waters become economically feasible, the solution has been sought in spreading the flood waters over as large an area of undeveloped parts as possible.

5.5. Experience of Embankments in other Countries

5.5.1. Embankments have been used as a means of protection against floods since the dawn of civilisation. Several countries like China and Egypt

have very long histories of embankment construction. Other countries such as Italy, Japan, America and others have comparatively more recent histories of efforts in fighting floods by means of dykes. Lessons arising from the experience of embankment construction in these various countries are briefly noted below. A fuller account is given in Appendix B.

5.5.2. In **China**, the first embankments were built over 2,500 years back. Although these did not always provide adequate protection where constructed, yet this has practically been the only method of flood protection adopted in that country until the advent of the present regime. There are thousands of miles of embankments in China sheltering nearly half the population of that country. Fifty-six per cent of the total arable area of China is protected by embankments. There have, however, been serious breaches in embankments off and on causing untold damage to life and property. Finding embankments alone neither a very dependable nor an adequate means of flood protection, the present Government felt the necessity of supplementing this method of protection by other methods of flood control. Several reservoirs have since been created and a few detention basins have been brought into use for moderating floods. These together with the embankments that already exist are now affording a greater measure of protection than ever before.

5.5.3. The Nile in **Egypt** has also a long history of flood control. This river, the second longest in the world, is completely embanked from Aswan to the sea, a distance of 1,200 kilometers. For prosperity and security against floods in the Nile valley people have for centuries depended upon embankments. These have not always proved invulnerable to high floods, and there is a record of serious breaches which occurred during the last century taking heavy toll of life and property. It was only with the construction of the Aswan dam in 1902 and its further raising in subsequent years that the Nile valley felt reassured against the menace of ever-recurring breaches in embankments.

5.5.4. The Po in **Italy** has an elaborate system of dykes dating back to hundreds of years. These had been raised, repaired and strengthened from time to time. It is reported that centuries back the Po was a restless and meandering river which occasionally changed its bed, but on account of the construction of dykes the river is now confined to a single channel which it has developed for itself. The delta of the Po has steadily been advancing into the Adriatic sea, having extended by more than 15 miles during the past 2,000 years. This increase in the length of the river has been a factor in raising the bed and the low water surface of the Po in its lower reaches. During this time higher floods have been experienced in the lower reaches of the river.

Dykes on the Po have, by and large, been found successful and have afforded good protection to the areas sheltered by them.

5.5.5. In **Japan**, history has recorded construction of embankments as early as during 710—858 A.D. In comparatively recent times, embankments, though still forming the main means of flood control, have been supplemented by other methods of flood moderation such as construction of dams and creation of detention basins. Soil conservation is being given great importance in this country.

5.5.6. In **America**, the earlier flood control works took the form of levee construction. On the Mississippi the first of this system was completed in 1727. In 1851, other methods, such as enlargement of natural river outlets, creation of artificial outlets and construction of reservoirs, got suggested. In 1861, however, opinion was in favour of "levees only". This opinion was reiterated in two subsequent important reports submitted in 1897 and 1913. In 1927, however, the Mississippi experienced disastrous floods, and it became apparent that the protection afforded by embankments alone could not be relied upon during very high floods. Additional measures were, therefore, thought out and carried out during the course of the next few years. Thus, as in China, while embankments form the main defence against floods on the Mississippi other control measures have been adopted for ensuring more dependable protection.

5.6. River Morphology

5.6.1. At this stage it would be appropriate to consider the morphology of rivers, particularly the Himalayan rivers. Wadia in his book 'Geology of India' has stated that "in the extra Peninsula the drainage system, owing to the mountain building movement of the late tertiary age, is of much more recent development, and differs radically in its main features and functions from that of the Peninsula. The rivers here are not only eroding and transporting agents but are also depositing agents during their journey across the plains of North India out of a part of the silt they have removed from the mountains". Pirsson and Schuchert (1920) have stated that the Ganga has eroded its basin "at the rate of one foot in about 1750 years". This is comparatively rapid, but the Himalayas are the highest mountains in the world and the basin is subject to very heavy rainfall. R.D. Oldham (1917) from a study of geological data concluded that the Indo-Gangetic trough had some 15,000 to 20,000 feet of alluvium, the trough being barred to the south under the surface of the Bengal plains by rocks connecting the Peninsula series with those of the Shillong hills. A bore was put down in Fort William, Calcutta, by Captain Sherwill (*vide* Hooghly Drainage Report, 1919). It yielded 481

feet of alluvium without touching bedrock. This shows the extent to which the Ganga has built its plain through ages.

5.6.2. Wadia has further stated that many of the great Himalayan rivers are older than the mountains they traverse. He has explained that during the slow process of mountain formation by the folding, contortion and upheavel of the rockbeds, the old rivers kept very much to their own channels. Thus, several of the great Himalayan rivers, *e.g.*, the Indus, the Sutlej, the Bhagirathi, the Alaknanda, the Kali, the Karnali, the Gandak, the Kosi and the Brahmaputra drain not only the southern slopes of the Himalayas but to a large extent the northern Tibetan slopes as well.

5.6.3. The rivers of the Peninsula drain a much older and stabler land formation. The process of erosion of the mountains and hills, thus degrading the land there and of building up or aggrading the plains is less marked in the Peninsula than in the Himalayan tract.

5.6.4. Rivers thus transport silt and sediment from the hills to the sea. In the upper reaches where the slopes are steep and the velocities are high, the rivers are able to carry along the silt and sediment which pours into them from their catchments. On emerging into the plains, with flatter slopes the silt transporting power of rivers decreases markedly. Depending upon the quantity of silt which the flood waters are required to carry the river succeeds in transporting the sediment or unburdens itself of a part of the silt load by depositing it either in the bed or on the flood plains on spilling the banks. The intensity and grade of silt and the bed slope are thus the governing factors which go to determine whether a river is aggrading or degrading.

5.6.5. In nature no river is truly stable, as the process of erosion in the hilly catchments, the transportation of sediment thus washed into the river and its subsequent deposition somewhere lower down must continue. There are, however, some rivers which manage to transport most of the sediment, if not all of it, to the sea, where it is dispersed as littoral drift. These rivers do not show any apparent natural tendency towards overall raising or lowering of their beds, and thus may be regarded as stable. Mr. Jerard H. Matthes of the U. S. A. has aptly called such rivers "Poised rivers" instead of stable rivers. Of larger rivers, examples of such poised rivers are the Yangtze, the Mississippi, the Nile, the Ganga, etc. The rivers of the Peninsula are, by and large, poised rivers and in consequence do not present any serious flood problem.

5.6.6. In contrast to nearly stable or poised rivers there are aggrading rivers, which are unable to transport the silt and sediment which gets into them from their hilly catchments. In India the notable examples are the Brahmaputra, the Kosi and the Tista. The Indus in Pakistan is another

notable example of an aggrading river, which has shown a mean rise of river bed at Kotri of 0·061 foot per year.

5.6.7. The Brahmaputra, although it rises in Tibet and drains the northern slopes of the Himalayas, yet it derives bulk of the flood volumes from the copious rainfall on the southern slopes of the Himalayas and the Assam, range of hills. The outer ranges of the Himalayas consist of softer rocks which yield heavy silt and sediment due to the copious rainfall in the area. This region is also liable to severe earthquakes. Heavy landslides occur in this region during the monsoon when the steep slopes, on saturation during the monsoon, become unstable. Heavy landslides also take place whenever earthquakes occur. The Brahmaputra, in consequence, is unable to transport all the detritus that pours into it from the various tributaries, particularly in its upper reaches in Assam. As a result of this the bed of the river has shown a tendency to rise in its upper reaches. This has been very marked after the earthquake of 1950 when numerous landslides occurred in the hills. The low-water level at Dibrugarh has risen by about 10 feet since this earthquake. As a result of siltation of bed of the Brahmaputra in its upper reaches flood heights have been increasing there. The effect of this choking of the riverbed in its upper reaches has not yet been felt to a very great extent lower down in the Gauhati reach, as the detritus from above has not moved in any appreciable quantities. When it does move down aggradation and consequently higher flood heights are to be expected in the lower reaches.

5.6.8. Like Brahmaputra, the Kosi also drains part of the northern slopes of the Himalayas. One of its tributaries, the Arun, cuts right across the great Himalayas. The Kosi brings an abnormal silt load, the bulk of it contributed by the outer Himalayas consisting of coarse silt, which the river is unable to carry much beyond the Nepal-Bihar border where the slopes flatten out considerably. Thus, in this reach where the coarse silt gets deposited the river is aggrading and in consequence is markedly unstable.

5.6.9. The Tista also brings an abnormal silt load particularly from hills around Darjeeling, where there has been large scale deforestation in recent years and which in consequence is yielding very heavy silt load from copious rainfall in the area. The river in consequence is increasingly aggrading.

5.6.10. These are but a few examples of aggrading rivers. There are many other tributaries draining the Himalayan slopes which are aggrading.

5.6.11. Neither a poised river nor an aggrading river has uniform behaviour all along its length. For instance, a river while aggrading in its upper reaches may be quite stable lower down, the stability being indicated generally

by a deep, well-defined and a meandering channel. On the other hand, a nearly stable or poised river can deposit large masses of sediment in its bed and in the flood plain in the delta area, and is thus aggrading in that reach. In viewing the problems of a river, therefore, the different characteristics of the river in its various reaches have to be borne in mind. Therefore, there can be no generalisation regarding the suitability of constructing embankments on a particular river applicable to its entire length.

5.7. Effect of Embankments on Aggrading, Degrading and Poised Rivers

5.7.1. Aggrading rivers generally take a braided form, braiding being the result of the river's incapacity to transport the heavy sediment which it brings from above. During high floods, when the river spills over the banks the silt-laden spill water unburdens itself of its silt load thereby raising land along the banks. Such raising is greater near the river and less and less farther away from it. The effect of constructing embankments on a river which is aggrading would be to prevent spilling of the silt-laden waters beyond the line of embankments. Therefore, unless the silt gets pushed down the river, it has to deposit in the area confined within the embankments. This may lead to accentuation of aggradation. If embankments in a long reach of the river are close enough and the flood waters flow with sufficient increase in concentration and flood heights, the river channel will have improved silt transporting capacity and is likely to develop into a better defined and deeper channel. This, of course, presumes that the embankments are held against attacks of the river. As an instance, the Po in Italy might be cited. This river, it is reported, used to be a braided river centuries back. After the construction of embankments its regime improved, and now it flows in a much more defined and well-formed channel. On constructing embankments on a braided river the process of the formation of a more defined channel, however, takes a fairly long time.

5.7.2. Degrading rivers, which as a rule flow in deep channels and in consequence do not normally spill, seldom require construction of embankments for preventing flooding of areas. There can, however, be short reaches along degrading rivers which because of their low ground levels do get flooded in very high floods. Construction of embankments to protect such reaches would not have adverse effect on the river channel, which will continue to show a degrading tendency. In course of time as degradation proceeds, lower flood heights will obtain and increasing freeboard would be available at the embankments. Of course, where long reaches of a degrading river are embanked increased flood heights resulting from confining flood waters within the embankments must obtain, although the riverbed itself would not rise.

5.7.3. On poised reaches of rivers, which implies that the river is able to transport, by and large, whatever sediment comes in from above,

the construction of embankments does not have any adverse effect on the riverbed in such reaches. In fact the confined flood flow within the embankments tends to deepen and widen the river to enable it to carry within the embankments what previously flowed over a bigger width. Construction of embankments over long reaches on such rivers would initially result in increased flood heights, which in course of years would tend to drop down to pre-embanked flood heights.

5.7.4. Where floods cause damage to crops and other property they confer some benefits also. Spill waters decanting over river banks generally carry fine and medium silt. The fine silt has manurial value, and gives excellent crop after flooding of the area. Also flushing of areas with spill waters sometimes improves health conditions in the area, as all stagnating waters where disease-carrying insects breed get flushed. Flooding of areas is the means by which a river carries on its land-building activity. When spilling is prevented by building embankments, these beneficial activities are automatically precluded.

5.8. Extension and Raising of Deltas and the Effect of Embankments there

5.8.1. As has been stated earlier in this report the larger rivers transport colossal quantities of silt and sediment from their catchments to the sea. During wet season rain washes enormous quantities of material loosened by weathering and other natural causes into rivers. Snow melt and glaciers also contribute some silt. Part of this sediment coming down from the hills and highlands gets deposited in the flood plain, the rest being carried to the sea to help in the formation and extension of deltas.

5.8.2. The quantity of sediment which a river brings depends on the size and nature of the catchment and the rainfall in the area. A river like the Yellow having very soft loess area in its catchment can bring at times an abnormal quantity equal to 50 per cent by weight of its flood discharge. The sediment transported to the sea gets, by and large, deposited near the mouth of the river, thus extending the delta at a rate governed by the quantity of sediment brought in, the slope of the sea-bed at the mouth of the river, and the behaviour of the tides. Thus the rate of advance of deltas of the various rivers varies. The Mississippi delta has been advancing into the sea at a rate of 6·5 kilometers or about four miles per century. On the Yantze-Kiang, the delta has advanced by 30 miles into the Yellow sea during historic times. On the Yellow river measured along the rivercourse today the shoreline in 5,500 B.C. was 500 kilometers landward from its present position. This gives an advance of one kilometer (0.6 mile) every 15 years. The sea-bed at the mouth

of this river slopes at a slope of one in 3,000. The Po in Italy is a small river having a length of 425 miles and a catchment area of 28,000 square miles, and brings a comparatively smaller quantity of sediment. Here the delta has advanced by only 15 miles during the past 2,000 years.

5 8.3. As with the extension of the delta the rivercourse lengthens, the bed of the river in the lower reaches rises and higher flood heights obtain. With this gradual and progressive rise in the bed and consequent higher flood heights, the silt-laden flood waters spilling over the banks raise the deltaic land. In this process the tides help a lot. When the silt-laden waters of a river come in contact with the sea the silt in suspension drops down on the velocity being checked. The tides rising twice a day keep the shore waters in a state of agitation and the silt brought down by the river is dispersed over a wide face. The rising tide moving up the river carries with it an enormous quantity of silt picked up from the sea near the mouth of the river, and on the tide waters spreading over low lands in the delta the silt is deposited there, thus continuing the process of raising of these lands. During the period of ebb, water from these inundated lands flows back into the river, but it is relatively silt free, the silt having been deposited on the lands. This silt-free water flowing down the river back to the sea helps in keeping the river mouth open.

5.8.4. When embankments are built along the river channel in delta areas and particularly when embankments are also built along the sea face they prevent tide waters from inundating land. The land-raising activity in the area is checked. Therefore, with the extension of delta and consequent raising of riverbed with resultant higher flood heights, these lands deteriorate on account of the difficulty of drainage. Waterlogging occurs, the soil deteriorates and health conditions also go bad. The protective embankments become increasingly vulnerable and require progressive raising and strengthening. It is apparent that these adverse effects would be commensurate with the rate of extension of the delta. If any particular delta does not extend appreciably,—and there can be situations where delta extension is very slow indeed,—*status quo* is more or less maintained, and no serious adverse effect becomes apparent over a very long time. The effect of premature embanking in delta areas is dealt with in para 5.10.

5.9. Deltas of Indian Rivers

5.9.1. A study of conditions obtaining in the deltas of some of the more important rivers of India reveals interesting results. The table overleaf gives some relevant information in this connection. The sea-bed slope at the mouth of these rivers is shown in the facing diagram. Each of these deltas is discussed in the paragraphs that follow.

FACING PAGE 40

SEA BED SLOPE AT THE MOUTH OF SOME RIVERS IN INDIA

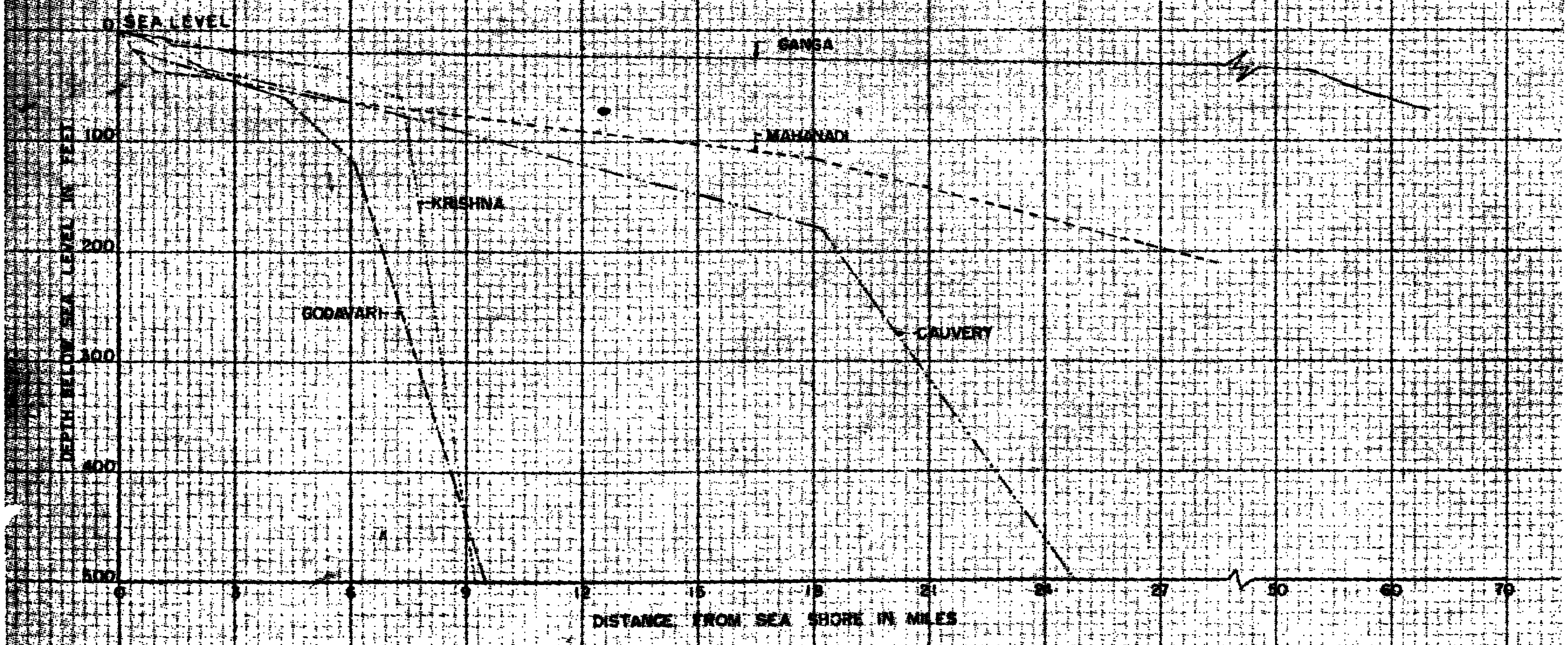

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Table of the More Important River Deltas of India

Sl. No.	Name of river	Length of the river in miles	Catchment area in sq. miles	Mean bed slope in the lower reach	Length of the delta in miles (approx.)	Width of the delta in miles (approx.)	Tide height in feet	Distance of steep sea-bed slope from shore in miles	Rate of extension
1	2	3	4	5	6	7	8	9	10
1	Ganga (Meghna)	Ganga 1557 Brahmaputra 1800	Ganga 4,14,313 Brahmaputra 2,27,330		272	Over 250	10.5 to 19.5	50	No extension noticeable at Hooghly. Extensive shoal formation at the mouth of Padma, though no continuous extension of mainland.
2	Mahanadi	533	51,000		65	Over 75	3.5 to 8.5	20	4 miles in 40 years. Length of river increases by 16 miles.
3	Godavari	937	1,21,500		45	52	2.4 to 6.7	18	No appreciable extension at the mouth. About four miles along littoral drift.
4	Krishna	775	97,050		10	14	2.0 to 5.0	7	2 miles in 130 to 141 years over a face of 14 miles.
5	Kaveri	440	31,000		2	7	0.7 to 3.4	5	No extension over a century.

5.9.2. The Ganga-Brahmaputra system has a very extensive delta which extends over more than 250 miles of sea face. Till the end of the 15th century the Bhagirathi constituted the main course of the Ganga. With the breaking of the Ganga into the Meghna on its east the main outfall of the river has shifted to the Meghna, the Bhagirathi, and in consequence the Hooghly taking but a small fraction of the flood discharge. The result of this change has been that the delta-building activity at the mouth of the Hooghly has ceased. In fact records of Port Commissioners show that the sea face at Sagar island at the mouth of the Hooghly has been eroding since the 18th century. Therefore, the adverse effects resulting from delta extension do not obtain on the Hooghly. No records are readily available to show to what extent the delta has extended at the mouth of the Meghna in Pakistan. A comparative study of survey maps prepared in 1851-63 and 1914-32 shows that there has been a fair amount of deposition of silt at this estuary during this period of 63 to 69 years. The estuary here is so very wide that no lengthening of the rivercourse of the Meghna need be expected for several hundred years to come. Therefore, no marked change in the river regime higher up is to be expected on the Ganga or the Brahmaputra on account of the extension of the delta. The tide height at the mouth of the Hooghly ranges between 10·5 to 19·5 feet. This excessive tide height in the funnel of Bay of Bengal is responsible for the dispersal of silt brought down by the Ganga-Brahmaputra river system over a very wide area and in consequence the extension of the delta is relatively less marked.

5.9.3. The Mahanadi is comparatively a smaller river and brings much smaller quantity of silt and sediment than the Ganga-Brahmaputra river system. The tide height at its mouth varies between 3·5 feet and 8·5 feet and is much less than that obtaining in the Bay of Bengal. The steep sea-bed is about 20 miles away from the shore as against over 50 miles in the case of the Ganga. The silt which the river brings into the sea is dispersed in the shape of a long bar by a littoral drift, which moves the sediment along the shore in a north-easterly direction. This narrow bar temporarily increases the length of the rivercourse at its mouth, giving higher flood heights till the bar breaches near the original mouth of the river, thus short circuiting its course to the sea. A comparative study of survey maps prepared in 1888-89 and 1928-29 has shown that a bar 16 miles long and three miles away from the original shore was formed during this period of 40 years. Thus, on the Mahanadi we have the phenomenon of increasing flood heights over a period with a period of relief whenever the long bar at its mouth breaches. With the construction of Hirakud Dam, however, a change is to be expected in the rate of deposition of silt at the mouth of this river and the consequent extension of the delta.

5.9.4. The littoral drift at the mouth of the Godavari is fairly strong. In consequence the deposition of silt and the resulting delta extension takes

place at the northern end. The river, by and large, maintains its length, as it flows more or less straight into the sea. No raising of flood heights has in consequence been experienced in the lower reaches of this river over long periods. Of course, very high floods have off and on been experienced on this river due to abnormal rainfall in the catchment. This river has very old embankments in the delta region, and these embankments seem to have served the purpose well.

5.9.5. The Krishna has a short and narrow delta. Here the tide height varies only from two feet to five feet. This river with a catchment of almost a lakh square miles, coming from the more stable region of Deccan plateau, brings comparatively much smaller quantities of silt than most of the Himalayan rivers of similar size. A comparative study of Survey of India maps prepared in 1786-1800 and 1927-30 show an extension of the delta by two miles over a width of 14 miles in a period of 130 to 141 years. The effect of the lengthening of the delta, and in consequence of the river distributaries, has been felt in the shape of some rise in the bed levels of the river and higher flood heights. Embankments have existed on this river for a pretty long time now. The maximum flood discharge recorded on this river was 11·94 lakh cusecs in 1903. A flood of similar intensity was experienced in 1949 when it submerged considerably more area and to greater depths than in 1903. It is now reported that in the lower reaches of this river flood levels are reached with only three-quarters of the previous discharges. Of course, the construction of Tungabhadra Dam now helps in moderating floods in the river, and when the Nagarjunasagar Dam is completed the floods would be further moderated.

5.9.6. The Kaveri delta has shown no signs of extension for almost a century, as is apparent from a comparative study of surveys made in 1791-1855 and 1929-1931. In fact, there are no flood problems worth the name on this river.

5.9.7. The Narbada and the Tapi on the west coast have practically no deltas worth the name. In consequence no problems resulting from delta extensions arise there.

5.10. Premature Embanking of Delta Lands

5.10.1. With enormous quantities of silt and sediment coming down the river and getting deposited near its mouth, existing delta lands get extended and fresh shoals appear at the mouth. These later develop to form islands, which in due course get covered with vegetation and later get inhabited. Delta lands

being fertile generally have a big density of population. There is the ever-present demand for more and more land to sustain this population. In consequence, whenever some new land appears as a result of delta-forming activity of the river there is the temptation to put the newly formed land to human use as soon as it is possible. This is generally done by throwing an embankment round the newly formed land to keep the high tide waters out. More often than not such reclamation is done before the land is sufficiently raised by river and tidal action. When land is thus prematurely reclaimed it prepetually keeps low and creates many problems, which accentuate as the delta extends or the surrounding lands rise in level. The drainage of such enclosed areas become difficult, waterlogging takes place, the soil retains salinity and the raising of more than one crop, generally paddy, becomes difficult.

5.10.2. The Sunderbans in Bengal is a typical case in point. According to a report published by the Government of West Bengal in 1950, the Sunderbans comprise 3,089 square miles out of the total area of 5,257 square miles of the 24 Parganas district. Of 1,620 square miles reserved forest area in Sunderbans 897 square miles is land, the rest being area under water. On account of pressure of population 1,460 square miles of forest area got released of which 976 square miles are under cultivation. The density of population in the settled and inhabited parts varies from 250 to 450 persons per square mile. There are 2,200 miles of embankments in Sunderbans area constructed mostly by zamindars and private individuals. These have been taken over by Government for maintenance. The Sunderbans area, which has numerous interlacing channels, has a mosaic of islands of varying sizes. Covered previously with forests and scrub jungle most of these islands are now under cultivation having been reclaimed by ring bunds built along the periphery. In many cases these reclaimed areas are five to six feet below high tide level. The fertility of the soil is low on account of continued salinity there, and is getting worse due to waterlogging. This poses a serious problem. The solution lies in throwing open these islands one by one to tidal action again so that the land is raised to, say within a foot of the high tide level. In one or two instances where the encircling embankments got removed in part, thereby admitting silt-laden waters, the land raising has been remarkably rapid being sometimes three to four feet in a single year. This process of raising prematurely reclaimed lands would undoubtedly pose administrative difficulties, but unless these lands are raised to a reasonable height the existing unhappy conditions must continue there.

5.10.3. The premature reclamation of land is not peculiar to India only. Other countries have had similar experiences. Burma has similar problems on the Irrawaddy. Dealing with the effects of embankments on the Irrawaddy Mr. McIntosh, Chief Engineer, Burma, stated not many years ago that

eventually it would be necessary to remove long stretches of the Yandoon and Thongwa embankments to silt up the interior. He had, however, doubted the practicability of removing these embankments as he felt that the landowners would not agree to be "drowned out" for the sake of future generations. It is, however, apparent that the situation which is progressively deteriorating will have to be tackled in this manner sooner or later.

5.10.4. While action needs be taken to remedy the prematurely reclaimed areas, it is very important that further land should not be reclaimed prematurely howsoever great the temptation or need of the time be. Provision to this effect exists in the Bengal Embankments Act. The provision will need to be enforced vigorously.

5.10.5. Where a delta is extending rapidly it would be undesirable to embank the river in the lower reaches as otherwise the rising flood levels would perpetuate the problems of drainage and waterlogging in the adjoining area.

5.11. Effect of Embankments on Rivers

5.11.1. The immediate effect of confining the flood waters of a river between embankments is:—

(1) to increase the rate at which a flood wave travels down the river,

(2) to increase flood heights in the embanked reach for any given flood,

(3) to increase the maximum discharge downstream, due to reduction in valley storage,

(4) to increase the velocity and the scouring action in the embanked reach, and

(5) to increase the flood height and in consequence to decrease the surface slope upstream of the embanked portion, on account of the afflux caused at the head of the embankment due to their confining and constricting effect.

5.11.2. On an unembanked river the progress of a flood wave downstream is delayed by the loss of the water which spills over the banks. The water thus spilled may find its way back into the river lower down, but the process of spilling brings into operation valley storage, thereby moderating the flood peak, slowing down its velocity and lowering the flood heights along the river.

Thus, when the spilling is prevented by construction of embankments the flood heights increase with increased flood discharge, and the flood wave travels down faster.

5.11.3. With the increased velocity in the stream confined within embankments the capacity of the river to deepen and widen its bed, thereby enlarging its cross-section, increases. Actually, over a long period the river can revert to its pre-embankment flood heights. Another effect which over a long period can result is the improvement of the river channel from a braided pattern to a well-defined meandering channel, if the embankments can be built close enough and can be maintained, as has been reported to have been the case with the Po in Italy.

5.11.4. The afflux caused at the head of embankments by their stream confining action gives rise to higher flood heights upstream of the embankments. The extent to which these increased heights are experienced in any river depends on a number of factors, such as the flood discharge, the river slope, the extent of spilling upstream of embankments, and the constriction caused by the embankments. These increased flood heights upstream of embankments can give rise to demand for extending the embankments further upstream.

5.11.5. The long-range effect of embankments on a river depends on what type of river it is. A river can bring enormous quantities of coarse sediment and may have very steep slopes in its upper reaches with comparatively gentle slopes lower down. The Kosi, the Tista, the Brahmaputra, etc., can be cited as examples. On the other hand, there can be rivers, such as the Yamuna, the Betwa, the Gomti etc., which bring down comparatively smaller quantities of coarse silt and have a relatively flatter and less markedly changing bed slope. Rivers of the former type are generally aggrading and flow in a braided pattern, the aggradation and braiding being more marked in the upper reaches where coarse material gets deposited as the bed slope rapidly flattens out. In an unembanked state such a river may even tend to change its course. The effect of embankments on such a river would be to confine the deposition of coarse material within the embankments thus accentuating aggradation. Of course, with higher flood heights and increased velocities within the embanked reach, the coarse material will be pushed some distance further down than in the unembanked state. On rivers of this type it is rarely that embankments can be built close enough all along to induce high enough velocities to enable the river to transport the coarse material to the main river of which it is the tributary. Embankments when built close in this manner are difficult to hold against river attacks.

5.11.6. On rivers or river reaches which do not carry much coarse sediment and which in consequence are stabler, the construction of embankments does not have any significant long-range adverse effect. In fact the construction of embankments on such a river helps in improving the river regime. The increased velocities induced on account of confining the flood waters to within the embankments help in deepening and improving the river channel. In course of time the flood heights, increased on account of construction of embankments, revert, more or less, to the pre-embanked stage. The Gandak which has been doubly embanked now for almost a century is a typical example of this category.

5.11.7. The magnitude of loss of flood moderating effect due to construction of embankments depends on the valley storage of the river. For instance, on the Yamuna, due to very good valley storage, a maximum flood discharge of 4·5 lakh cusecs at Tajewala in 1956 got reduced to only 1·76 lakh cusecs by the time it reached Delhi, 150 miles down. If this excellent valley storage is eliminated by double embanking the river all along, the flood height at Delhi must be considerably higher with possibly serious repercussions. Of course the channel storage and in consequence its flood moderating effect will still be there. In designing embankments on tributary rivers, therefore, the effect of loss of valley storage has to be carefully considered in relation to channel storage between the embankments and channel capacity downstream.

5.11.8. A tributary whose confluence with the main river is not restricted by a controlling structure such as a bridge behaves in certain respects like a river falling into the sea. Here, when the main river is in high flood, water backs into the tributary channel retarding velocities and leading to spreading of flood waters over considerable areas near the confluence. This in turn results in the deposition of a good deal of silt in this reach brought by the tributary river, the action being somewhat analogous to that obtaining in the deltas of rivers falling into the sea. In fact, a tributary river sometimes creates a small delta of its own at its confluence with the main river. This results in changes in the position of the confluence. The effect of embankments along a tributary river extending to the main river would be to ensure a more concentrated flow from the tributary into the main river, thereby creating conditions for keeping the mouth of the tributary open. This would discourage any tendency in the tributary river to change its point of confluence with the main river. Of course, extension of tributary embankments, right up to the main river and particularly when the main river is also embanked, may create serious drainage problems which may prove insoluble or prohibitively expensive of solution.

5.12. Flood Pattern in the Ganga and the Brahmaputra

5.12.1. The Ganga has a total catchment area of 4,14,313 sq. miles which lies almost entirely in Indian territory. The river is generally in flood from the middle of June to the end of October. In the lower reaches, that is in Bihar and Bengal, the flood heights show a progressive increase up to August. The general downward trend then commences sometimes in September, although the highest floods in some years have occurred in September and October. The maximum observed discharge of the Ganga at Farraka (1948) was a little over 21 lakh cusecs.

5.12.2. This river has a number of large tributaries, the more important being the Yamuna, the Chambal, the Betwa and the Sone from the south, and the Gomti, the Ghagra, the Gandak and the Kosi from the north. The maximum flood discharge at Farraka is only about one-third of the sum total of the maximum discharges of its various tributaries. The reasons for this considerable moderation in the maximum flood discharge in the main river at Farraka are :—

(i) Floods in the tributaries do not generally synchronise.

(ii) The outfalls of the various tributaries are staggered over considerabe distances, thus leading to a marked stagger in the contribution to the main river from these tributaries.

(iii) The considerably large channel capacity of the river and its tributaries as also the valley storage, both of which have a large flood moderating effect.

It is a happy situation that the monsoon currents travel up the river, thus affording a favourable dispersal in the inflow into the river resulting from heavy precipitations.

5.12.3. Although the Brahmaputra has a total length of 1800 miles, its length in the Indian territory is only 450 miles. This river traverses a thousand miles before it enters the Indian territory. Bulk of its flood discharge is received in the Indian territory where a number of tributaries drain the southern slopes of the Himalayas as also the Assam range of hills. For instance, in 1956 while the maximum discharge at Tsela Dzong situated at the lower end of the river in Tibet was only a little more than two lakh cusecs, that at Pandu (Gauhati) was 18·54 lakh cusecs and that at Dhubri was about 22* lakh cusecs.

5.12.4. As in the case of the Ganga so in the case of the Brahmaputra, the monsoon currents move more or less against the direction of flow in the

river. But the Brahmaputra valley is comparatively narrow, being only about 50 to 60 miles wide between the Himalayas and the Assam hills. The clouds moving along the valley, therefore, give a more concentrated precipitation resulting in the simultaneous flooding of a number of tributaries, though not all the tributaries are in flood at the same time. The effect of this is that there is not the same amount of stagger in floods of the various tributaries as in the case of the tributaries of the Ganga.

5.12.5. As has been stated above the high flood in the Brahmaputra is occasioned primarily due to heavy rainfall in the Assam valley itself, and under those conditions the countryside gets inundated not only due to spills from the Brahmaputra but also due to accumulation of rainwater. This narrow valley with its low-lying areas filling up whenever there is heavy rainfall affords but little flood absorption capacity, particularly as high floods in the Brahmaputra are at times prolonged. For example, the flood discharge at Pandu (near Gauhati) remained more than 17 lakh cusecs for half a month at a stretch towards the later part of June 1956. Even when the rainfall in the lower part of the valley is not very high, it does not take the Brahmaputra spill any appreciable time to fill up the valley storage. Therefore for most time of any high flood, the flood absorption capacity of the valley is negligible. In fact whatever flood moderation occurs in the Brahmaputra, is primarily due to the channel capacity of the river.

5.12.6. The width of the Brahmaputra in Assam generally varies between 3 and 7 miles. Flooding from the Brahmaputra extends generally between two to three miles on either side. The spill-water flowing through these inundated areas moves but slowly not only due to the slow velocities which generally obtain when the depth of water is small but primarily due to the obstruction afforded by standing crops, field bunds, habitations, tree growth, etc.

5.13. Embankments on the Ganga River System

5.13.1. On the Ganga river system, the more important of the tributaries which have recently been embanked or are proposed to be embanked in appreciable lengths are the Ghagra, the Burhi Gandak, the Bagmati, the Kamla and the Kosi. Of these the Burhi Gandak, the Bagmati and the Kamla are comparatively small rivers, the maximum flood discharge of the Burhi Gandak being about one lakh cusecs, that of the Bagmati being about 1½ lakh cusecs and that of the Kamla 90,000 cusecs. The Ghagra and the Kosi, however, are large rivers, the former having a maximum discharge of about a million cusecs and the latter an observed discharge of 8½ lakh cusecs in the gorge.

5.13.2. The Ghagra has a length of about 320 miles in the plains, of which a total length of 195 miles has been singly embanked in the various

reaches on one bank or the other. This river has a bed width of 4 to 6 miles. These embankments, built a mile or so away from the river bank still leave a large channel capacity for moderating floods. The Ghagra embankment will, however, have the effect of increasing the peak flow somewhat in the Ganga below its confluence.

5.13.3. On the Kosi, embankments have been built over a length of about 75 miles on either side in its middle reach. These embankments are a considerable distance apart, the maximum distance in the middle portion being 10 miles. With embankments so far apart there cannot be any large loss of flood moderation due to channel and valley storage capacity. Also, since more than 70 miles of the length of this river in its lower reach are not embanked, there is considerable waterspread in that reach which provides for appreciable flood moderation.

5.13.4. Besides the tributaries mentioned above there are no other tributaries on which embankments are proposed to be constructed in any long lengths, nor is it proposed to embank the main river in any continuous long reach. The embankments on the three comparatively smaller tributaries, namely, the Burhi Gandak, the Bagmati and the Kamla, will have the effect of raising flood peaks in the Ganga. The Bagmati and the Kamla fall into the Kosi before their waters reach the Ganga, and in consequence their floods get appreciably moderated by the time they reach the Ganga. Since the maximum flood discharges of these tributaries are comparatively small, their accentuating effect on flood peaks in the Ganga would also be correspondingly small.

5.13.5. In the Ganga river basin, a number of reservoirs have been built or are being built. The larger of these, namely, the Gandhisagar Dam on the Chambal (storage capacity 6·85 million acre feet) and the Rihand Dam on a tributary of the Sone river (storage capacity 8·87 million acre feet) alone would exercise an appreciable flood moderating effect. For instance, it has been calculated that a flood of 7·9 lakh cusecs at Rihand Dam, when routed through the reservoir, would be reduced to a maximum flow of 4·5 lakh cusecs.

5.13.6. It has not been possible for the Committee to make detailed calculations to assess the increase in the flood flow peaks in the Ganga due to the construction of embankments on the tributaries mentioned above. The necessary data for making this appraisal is not available at present, nor had the Committee sufficient time at their disposal to undertake these detailed studies. From a general study of the conditions the Committee are, however, of the view that the flood moderating effect of the various reservoirs recently constructed or under construction would more or less offset the increase in flood

flows caused by the embankments already constructed or planned to be constructed in the current Five Year Plan.

5.14. Embankments on the Brahmaputra River System

5.14.1. Considerable length of embankments constructed recently on the Brahmaputra and its tributaries is located in the eastern part of Assam, although the main river has been embanked in certain lengths in the lower reaches also. Prior to 1950, the river used to have a comparatively well-defined channel in the eastern part of the State also. But the earthquake of 1950 brought in such colossal quantities of debris into the river that the river channel got badly choked in its upper reaches. In fact, since the great earthquake the minimum flood levels at Dibrugarh have risen to more than 10 feet above those which obtained there before. Higher flood heights have been experienced in the upper reaches of the river ever since. These higher flood heights resulted in increased spilling over the banks and consequently greater inundation of areas. It became necessary to put in embankments in those reaches to remedy this flooding.

5.14.2. Of the tributaries which join the Brahmaputra in the lower reaches in Assam, long lengths of embankments are proposed in North Gauhati area on the Nona, the Baralia, the Pagladia, etc. These tributaries are, however, comparatively small streams, which rise in the outer Himalayas and have small catchment areas. Their normal aggregate contribution to the flood discharge of the Brahmaputra is of the order of 50,000 cusecs.

5.14.3. The embankments where proposed along the main river are kept a mile to a mile and a half away from the river bank. Thus between two opposite embankments on the river a width of nearly 7 to 9 miles obtains. The effect of preventing river spill beyond the line of embankments would be to confine the entire flood flow within the embankments. This must naturally tend to give higher flood heights. It has not been possible to calculate the increase in flood heights which might be experienced as a result of construction of embankments on this river, because there is not sufficient data available for making such a study. As explained in paras 5.12.6 and 5.12.7 the actual discharge which has flowed in the past through the flood plain outside the embankments has been only a small fraction of the total discharge which this river carries. It is the opinion of the Committee that any increase in the flood heights resulting from the construction of embankments already completed or contemplated would be small because of the great width of the river and the small loss of valley storage. The Committee are of the view that no serious adverse effects from this small increase in flood heights are to be apprehended if the embankments which still remain to be constructed during the Second Five Year Plan according to the

proposals contained in the Outline Plan for Flood Control in Assam are permitted to be completed. These embankments would afford protection in a width of a couple of miles on either bank, which is significant in a narrow valley of 50 to 60 miles width.

5.15. Embankments on other Rivers

5.15.1. There are no big schemes of embankment construction on other major rivers in the country. The few embankment schemes that are there have no inter-State repercussions. These schemes are mostly confined to deltaic areas, and this has already been dealt with in the earlier part of this chapter.

5.16. Embankments in the Third Five Year Plan

5.16.1. It is, however, felt by the Committee that any future programme of construction of embankments on the Ganga and the Brahmaputra river systems should be preceded by a more detailed appraisal of the resulting effects of such construction. Therefore, while the Committee feel that the construction of embankments on these two river systems during the current Five Year Plan as already planned is not objectionable, they emphasize the desirability of making adequate studies now of any proposals which the State Governments may have in view for inclusion in the Third Five Year Plan.

5.17. Construction and Maintenance of Embankments

5.17.1. The Embankment Manual prepared by the Central Water and Power Commission in 1956 deals with the matter of investigation, design, construction and maintenance of embankments. The engineer-officers responsible for construction and maintenance of embankments should follow the instructions contained in this Manual carefully.

5.17.2. The Committee do not wish to take up space in elaborating on these instructions, but wish to emphasize that it is of utmost importance to have a satisfactory arrangement for the maintenance and repairs of embankments once these are constructed. No embankment can be expected to survive the onslaught of a river for any length of period if its maintenance is neglected. It is important to have speedy means of communication and transport along the various embankments so that in an emergency steps to prevent any disaster can be taken. The embankments should be closely watched during flood season, and adequate material and equipment kept handy for dealing with any breaches.

5.17.3. Long lengths of embankments have been built on certain rivers in the country in recent years based on incomplete data and inadequate studies.

These works were taken up on emergency basis, in order to reduce serious losses which recurring floods had been causing in these areas. There has been and still is, a paucity of data. Also for satisfactory designs of embankments, hydrological data extending over many years are essential. Where these data are not available and the situation does not admit of postponement of execution of works till adequate data are collected, the works have perforce to be designed, based on whatever record is available. In most cases data of rainfall are available for longer periods than the data for river flows and river gauges. Adequate use of rainfall data does not seem to have been made in carrying out studies while designing embankments constructed during the last three or four years. It is recommended that future designs should be based on more comprehensive studies of whatever data are available. It might be remarked here that many breaches in the embankments recently constructed have occurred undue to overtopping which indicates that the flood flows in those rivers were under-estimated, or the increase in flood heights due to construction of embankments was not allowed for. Where data are inadequate it is better to make a generous allowance in the freeboard.

5.18. Suitability of Embankments as a Method of Flood Control

In general, embankments are a satisfactory means of flood protection when properly designed, satisfactorily executed and adequately maintained, in locations where construction of embankments is technically indicated. But a suitable combination of this method with other methods, such as storage dams, detention basins, etc., is more efficient and desirable. It is important, however, that those who expect protection from floods by means of embankments should know their limitations.

CHAPTER VI

Other Methods of Controlling Floods or Reducing Flood Losses

6.1. Various Methods

6.1.1. The main object of flood control is to reduce to the extent possible loss of life and property resulting from the visitation of floods. The methods of reducing flood losses fall into two general categories. Firstly are the methods for physically controlling floods by reducing flood heights and/or areas of overflow and of checking bank erosion. Secondly are the methods which do not attempt to reduce flood flows or flood levels but aim at reducing or redistributing the resulting flood losses.

6.1.2. The methods of physically controlling floods besides the construction of embankments already dealt with in the previous chapter are as under:—

(1) Works to store or detain the excess volume of flood flows comprising—

(i) Reservoirs, and

(ii) Detention basins.

(2) Channel improvements or enlargements for enabling the river to carry the flood flows at lower water levels.

(3) Diversion of part of flood discharge into other natural or artificial channels and spillways, controlled or uncontrolled.

(4) Raising habitations above flood heights.

(5) Watershed improvements.

6.2. Reservoirs

6.2.1. **Floods occur when the river-flows exceed that which the river can carry within its bank. Reservoirs bring about flood moderation by withholding peak flood flows and releasing the stored water later in regulated quantities.**

6.2.2. For flood control, reservoirs to be of optimum value, these must have adequate capacity for dealing with all except possibly phenomenal floods. The cost of such artificial reservoirs, intended only for flood control, is generally prohibitive. These single-purpose flood control reservoirs come into use for short periods each year, which place them, in the absence of accrual of other benefits, at an economic disadvantage. As a rule, therefore, the flood protection by means of storage or detention reservoirs can only be contemplated in special cases such as the protection of important centres immediately downstream, or of a relatively small valley with dense population. No dam exclusively intended for flood control has yet been built in India. Instances of such dams in other countries are also exceptional.

6.2.3. The use of multi-purpose reservoirs, including flood control as one of its functions, is a comparatively recent development. A number of such reservoirs have been built in the various parts of the world since the beginning of the century. In India, the D.V.C., the Hirakud and a number of other multi-purpose projects taken up recently have flood control as one of the objectives. In fact, a number of these projects were originally conceived as flood control projects, but irrigation and power, bringing direct financial returns, have in most cases overshadowed the flood control aspect.

6.2.4. The impression seems to exist in the minds of people that by catering for power and other benefits by means of storage reservoirs, flood control can be secured as an incidental benefit. This belief is not quite justified. To be effective a reservoir must have adequate capacity set apart exclusively for flood control purposes, and this means an extra height of the dam specifically for this purpose. It may, however, happen in many cases that with a comparatively small additional height of the dam, which in the upper portion gives relatively larger reservoir capacity the cost of storage for flood control purposes may work out cheaper than for irrigation and power utilisation. Multi-purpose reservoirs, however, where not specifically designed to cater for flood control, can have, and in most cases do have, appreciable flood control benefits, inasmuch as the early floods when the reservoirs are generally low, get absorbed or moderated. These reservoirs may not afford relief towards the latter part of the season when they are more or less full, nor may they help to moderate to a large extent a very great flood, yet the relief they afford in the early part and possibly through a greater part of the flood season is valuable as it enables paddy to be sown and raised to surviving heights before it faces the risk of damage later in the season from any big flood.

6.2.5. The joint use of a reservoir for flood control and other purposes can have a number of combinations, such as flood control and power

generation, flood control and irrigation, flood control and navigation, or a combination of two or more of these purposes. But, by sacrificing some interest of one for the other, it is always possible to evolve a working arrangement for the reservoir to satisfactorily meet the needs of both or more purposes. Where flood control is one of the purposes of a reservoir it is mandatory to reserve the required capacity for that purpose and to utilise the balance for other purposes. Flood control demands dependable empty reservoir capacity while irrigation and power generation require dependable stored supply. Certain overlapping of the space reserved for a given purpose, however, is possible owing to the need for the maximum space required for the various purposes not synchronising, and it is permissible to encroach on the capacity reserved for flood control only after the flood season is over.

6.2.6. The problems of combining flood control and navigation are not very different from those of joint utilisation of flood control reservoirs with power and irrigation. No storage has yet been created in India with navigation as one of its major functions, and where multi-purpose reservoirs have been built in the country any benefits to navigation are incidental.

6.2.7. In flood moderation by means of reservoirs no protection is afforded to that part of the drainage area which lies above the storage dam, but because of the nature of terrain above such dams it is not often that protection is required. The beneficial effects of storage for flood reduction grow progressively less downstream of the dam not only due to contribution from uncontrolled tributaries, but also due to channel storage capacity.

6.2.8. With a single large reservoir on a river, like the Hirakud on the Mahanadi, where there is a considerable uncontrolled catchment area contributing below the dam, the operation of the reservoir is rendered complicated not only by the uncertainties of weather in the catchment of the reservoir but also by that between the dam and the flood plain lower down. Also the possibility of a flood being followed close on the heel by another flood cannot be precluded. Such twin floods are not unknown and can be fairly frequent under certain meteorological conditions.

6.2.9. When there are a number of reservoirs on a river system, releases of flood water have to be so timed that the cumulative effect anywhere down the flood plain does not by itself bring about a serious flood, with a possibility of further aggravation by local contributions of uncontrolled flow.

6.2.10. For satisfactory flood control the correct operation of a reservoir is of utmost importance, and often involves delicate timing usually complicated by weather uncertainties. It demands considerable skill, forethought and

experience on the part of those responsible for the reservoir operation even when the operation is carried out according to predetermined regulation. Often prompt decisions have to be taken and quick implementation of these is required. Where a reservoir serves the needs of more than one purpose, or where there are a number of reservoirs on the river or its tributaries the operation becomes very complicated and should only be entrusted to engineers who are competent and resourceful and in whom confidence, authority and responsibility can be reposed. Flood warning and flood forecasting provide valuable modern aids in the operation of reservoirs. Nevertheless, a lot still depends on the judgement of the man who is responsible for operating the reservoir.

6.2.11. In a multi-purpose reservoir with flood control as one of its functions, an exaggerated importance is apt to be given to its power and irrigation aspects because of the direct money returns which the releases of water for those purposes bring, and because the benefits from flood control are mostly indirect. Therefore, the temptation to encroach on the space apportioned in the reservoir for flood purposes is always there. This has to be firmly resisted by strict adherence to operating rules framed in advance keeping in view the flood control function of the reservoir. If encroachment on flood control space is allowed, the multi-purpose reservoir instead of being beneficial becomes a serious threat to those who rely on its flood protection. The repercussions of a flood occurring where least expected are far more serious than those where these are expected.

6.2.12. Storage reservoirs where built for flood control purposes do not provide an enduring remedy. They have a limited life. In an appraisal made in the U.S.A. a few years back, it was estimated that the useful life of 64 per cent of all reservoirs in that country was less than 100 years (Proceedings of American Society of Civil Engineers, June 1949). It is, therefore, a matter for serious consideration as to what would happen after a reservoir silts up to a great extent. Undoubtedly soil conservation and other silt control measures prolong the life of a reservoir, but the fate of every reservoir is that ultimately it must silt up considerably reducing its capacity very appreciably, if not eliminating it altogether. In the meantime, the river channel downstream shall have deteriorated, value of land in the flood plain appreciated due to a sense of security against floods, and further development will have taken place in the high water bed of the river. Later, with reduced effectiveness of the reservoir for moderating floods the area will again become subject to floods. The resulting loss is considerably greater demanding more expensive and more elaborate measures for remedying it.

6.2.13. The flushing effect of flood peaks on river channels is considerable. When, therefore, flood peaks are eliminated by the moderating effect of

reservoirs, the river channel downstream must deteriorate unless steps are taken to prevent it. River section there tends to adjust itself to suit the new conditions. When, therefore, a flood arises which the reservoir is unable to cope with, the flood downstream assumes an added serious situation.

6.2.14. With the improved method of construction and the care which is bestowed on in the design of dams the chances of failure of a dam are now getting increasingly remote. There have, however, been several failures of dams in this country as in other countries, and the lesson learnt should not altogether be forgotten. In the event of the failure of a dam the ensuing damage is generally catastrophic. This fact is worth keeping in view particularly in the northern and eastern parts of India where flood problems are predominating and where the occurrence of earthquakes, severer than ever before, cannot be precluded.

6.2.15. Flood control reservoirs, however, can be desirable and effective means of moderating floods, and when this method of flood control is combined with embankments very satisfactory results can be obtatined. In most cases the reservoirs would be effective for a number of generations. But, as has been pointed out earlier, creation of storage reservoirs purely for flood moderation is normally expensive and in most cases economically unjustified. When a multi-purpose dam, however, is built the provision of adequate storage capacity for flood moderation is often economically feasible.

6.3. Detention Basins

6.3.1. As distinct from reservoirs created by building dams, detention basins are the creation of nature improved and regulated by man to serve his needs of flood moderation. As a rule rivers flowing through alluvium build up their banks higher than the adjoining lands. Swamps and lakes get created where drainage of adjoining land is obstructed by this process of bank raising by river spills. During high floods, where the river is not embanked, water spills and flows into these depressions, later to flow back into the river. This process brings about flood moderation in the river downstream.

6.3.2. The flood absorbing depth of a detention basin being a function of flood lift in the river, is normally limited to a few feet. Therefore to be effective, the area of the detention basin has to be relatively large. Also the bigger the river the greater the size of detention basin required for moderating its floods. A river of the size of the Ganga or the Brahmaputra would require detention basins of aggregate area of many thousand square miles for bringing about any appreciable flood moderation. Such large swamps or lakes do not exist in the basins of these rivers.

6.3.3. This method of flood moderation can find application on a number of small rivers in the country. For instance, there are a number of swamps or 'beels' along some tributaries of the Brahmaputra and in the Barak valley as also in North Bihar which can be put to such use.

6.3.4. Swamps and natural lakes in the plains generally have gently sloping sides and a rise of a few inches in the water level there often leads to submergence of large area of marginal lands. These marginal lands can be saved from flooding by confining the lake area within a ring embankment, making arrangement for the drainage of the area thus protected by providing suitable one-way sluice valves. The capacity of natural detention basins can be considerably increased by thus embanking it round and its utility enhanced by providing regulating devices at intakes and exit.

6.3.5. Detention basins receive silt-laden flood water, and when after being retained in the basin for some time it flows out again, it is cleared of most of its silt contents particularly of the coarse and medium variety. This comparatively silt-free water on later flowing back into the river with its increased silt transporting capacity compensates to some extent for the reduction of the capacity of the river, due to supression of flood peaks, to flush the bed silt, thus assisting in river conservancy.

6.3.6. With the deposition of silt in detention basins, its flood moderating capacity must progressively decrease. When the basin is silted up to such an extent that its utility for flood moderation ceases to be appreciable, the fertile land which has thus been built up in the detention basin becomes available for cultivation.

6.3.7. Flood moderation by means of detention basins, where feasible, is generally the cheapest form of flood control. The land under the marshes or 'beels' hardly requires much land compensation, and the control works being of low head are relatively inexpensive.

6.3.8. No sizeable regulated flood detention basins have been created in India for flood moderation. A few are however contemplated on the various rivers in Assam, Bihar and U. P. These are all in a very preliminary stage of investigation.

6.3.9. Storage tanks built for purposes of irrigation automatically contribute towards flood moderation, particularly during the early part of rainy season when these are still depleted and can hold back considerable volume of water which otherwise would add to flood heights. Such flood moderating effect is very noticeable on the rivers of South India where there are thousands of irrigation

tanks built many centuries back. There are such tanks in Madhya Pradesh, Rajasthan and U. P. also. These tanks besides moderating floods, have helped in conserving soil.

6.4. Channel Improvements or Enlargements

6.4.1. A river or stream can be made to carry its discharge at lower levels by improving its hydraulic conditions. Such improvements can consist of one or more of the following:—

(i) Improving the cross-section by widening, deepening or making the section more regular.

(ii) Channel clearance whereby all local obstructions in the bed or on the sides are removed.

(iii) Straightening the channel, thereby improving flow conditions in the channel.

(iv) Cut-offs which reduce the length of the channel, give it a steeper grade and consequently higher velocities and lower flood heights for a given discharge.

(v) Lining the channel, thereby improving the coefficient of rugosity, and thus enabling the river to pass greater discharge for the same water level.

6.4.2. The enlargement of the channel of a large river by widening or deepening for purposes of flood relief is generally feasible only in short reaches such as lie within towns or such other situations where other methods of flood control are not feasible. The Jhelum in Kashmir, downstream of Wular lake is a typical case requiring channel enlargement and improvement for easing the flood situation in Kashmir valley.

6.4.3. Channel improvements over long lengths have been attempted on some smaller rivers in India such as the Kali Nadi in Western U.P., the Khirohi river in North Bihar, etc. In the case of the former the channel has been widened and straightened over a considerable length. In the case of the Khirohi the river channel has been desilted at certain places, widened and straightened. Also, waterway has been increased on a number of bridges on this river.

6.4.4. Channel clearance, which can take the form of removing snags from riverbed, removing jungle growth from shoals in the river or removing sand

bars and other obstructions in the river channel, when carried out judiciously and over a length of period can lead to permanent improvement in the flow condition in the river.

6.4.5. Straightening of the river channel, and the use of cut-offs has been tried successfully on some of the larger rivers in various countries. The Lower Mississippi river furnishes an excellent example of channel shortening by means of cut-offs. On this river a length of 331 miles has been reduced to 195 miles by means of 13 cut-offs and channel straightening at a number of places. This has enabled flood heights to be reduced by many feet along most of the length of the river.

6.4.6. The Barak in Assam is a meandering river with a deep and well-defined channel. As flood moderation by means of reservoirs has not been found to be feasible on this river, cut-offs together with local protection by means of embankments might be found a suitable means of meeting the flood problem there. This, however, requires a careful study, and checking up of any proposals by means of model experiments.

6.4.7. Lining of river channel with a view to stabilising and improving it has not been done on any river in India, but this method has come into use in certain countries with plentiful resources such as America.

6.5. Diversion and Floodways

6.5.1. When floods in a river cannot be moderated to safe flows by means of reservoirs, or when flood waters cannot be led safely through a particular reach of river even by building embankments, it is sometimes possible to make resort to diverting part of the flood flow into another channel or on to land where damage would be comparatively light.

6.5.2. The use of this method dates back to ancient times. The ancient Babylonians had controlled the Euphrates by escaping flood waters into depressions in the Arabian deserts. In Egypt, Amenemhat of the 12th dynasty had put the entire Nile valley under cultivation by constructing dykes on both banks and providing this great river with an escape into the wide and deep depressions of lake Moeris.

6.5.3. The Chinese are adopting this method of flood control on the Huai river, by utilising 4·5 million acre feet capacity of six lakes and two swamps for diverting nearly half of the maximum flood discharge of 4,60,000 cusecs at Cheng Yang Kwan into these lakes. In Japan, in order to protect important areas near Tokyo 40 per cent of the discharge of the Tone river is diverted into

the Edo river through a diversion channel. Perhaps the most notable example of diversion works is to be met on the Mississippi river in America. After the disastrous floods of 1927 the American engineers came to the conclusion that embankments alone could not cope with the floods of this river. 'The Jadwin Plan' for flood control adopted by the Congress in 1928 recommended four big floodways in addition to improvement in the levees of this river. Of these, the floodway at Birds Point having a capacity of 5,50,000 cusecs and intended to protect the city of Cairo, the floodway at Atchafalaya Basin having a capacity of 12,00,000 cusecs, and that at Bonnet Carre having a discharging capacity of 2,50,000 cusecs and intended to protect the city of New Orleans, were actually executed, while that intended to be built at Boeuf Basin was abandoned due to fierce opposition from owners of the land which the proposed floodway would have flooded. Thus, of 30 lakh cusecs design flood discharge of the Lower Mississippi at New Orleans 14·5 lakh cusecs are disposed of by the Atchafalaya and Bonnet Carre floodways.

6.5.4. The excess water of a river during floods can be diverted in one or more of the following ways :—

(a) From one river into another.

(b) Directly into the sea.

(c) On to arid zones.

(d) Into natural lakes or depressions.

(e) Into certain specified areas dyked or otherwise.

6.5.4.1. Diversion of excess water from one river into another is feasible only when the receiving river has the capacity to take such diverted flood discharge without creating serious problems along its own course. In Orissa, the diversion of some flood discharge of the Mahanadi into the Brahmini through the Birupa at higher stages affords relief lower down in the delta. During the high floods of 1872 out of a total flood discharge of 15 lakh cusecs in the Mahanadi, a discharge of 1·1 lakh cusecs was diverted into the Brahmini through the Birupa. Recently in Andhra, nearly half the flood discharge of the Budameru river has been diverted into the Krishna through a diversion channel having a capacity of 7,000 to 8,000 cusecs. This diversion now enables the Budameru to pass the residual floods safely while no difficulties are created on the Krishna by this diversion as it is too big a river to feel the difference.

6.5.4.2. Diversion of flood waters directly into the sea is generally resorted to for reducing flood damage in the lower reaches of a river as in the delta areas. The splitting up of the river into a number of channels at its delta is a natural process of flood diversion. The main delta area of the Ganga-Brahmaputra system lies in East Pakistan, and flood problems in the deltas of other rivers are not so acute. No large schemes of flood diversion into the sea are, therefore, contemplated in India.

6.5.4.3. The main arid zone of India lies in Rajasthan. Although irrigation of certain arid areas in Rajasthan has been planned, no flood diversion as such is contemplated there at present.

6.5.4.4. Diversion of flood waters into lakes or depressions has been dealt with in paragraphs on detention basins. There are no large lakes in India which can be put to such flood moderation use. To be useful, such a lake has to be upstream of the flood plain to which relief is to be afforded.

6.5.4.5. Lately many miles of embankments have been built in the country. These embankments in many cases are not designed to cope with very great floods. In several States breaching sections or spillways are being provided in these embankments to allow escape of excess flood waters into selected areas where the resulting damage would be least.

6.5.4.6. Although except for the Jhelum valley in Kashmir no ambitious scheme of floodways or diversion is at present contemplated in the country, yet this is a method which should be kept in view in preparing overall flood control plans of any river system. This method, which provides a safety valve in the case of very great floods, can avert or minimise what otherwise might prove to be catastrophic damage.

6.6. Raising of Habitations above Flood Heights

6.6.1. When it is economically not feasible to preclude floods from a certain area or when it is otherwise undesirable to prevent the annual inundation of areas during the flood season, raising of habitations or other important places is resorted to, to prevent damage to property and inconvenience to the inhabitants there. While submersion of cultivated land for some period is permissible and is even welcomed in certain places, it is obvious that flooding of habitations even for a short period is very harmful and is to be prevented to the extent possible. In the Eastern U. P. thousands of villages have been raised above flood level in areas which are subject to annual flooding. This enables people to live in security against floods, although at times surrounded by water. Enough space is raised at such

habitations to provide shelter for the livestock and stores. This method of facing floods can with advantage be used in Lower Bengal and such low localities in other States as are exposed to annual flooding and where flood moderation or flood prevention is otherwise not feasible.

6.7. Watershed Improvements

6.7.1. The main cause of flood damage is not so much as excessive flow of water in rivers as the excessive sediment which most of them have to transport. If, therefore, a basic remedy is to be sought to the flood problem in the country, efforts will have to be directed towards reducing the excessive sediment which flows in the more damaging rivers. This means carrying out extensive and intensive land management measures in the catchment areas of these rivers. This matter is very important and has been dealt with more fully in the next chapter.

6.8. Methods of Reducing Flood Losses

6.8.1. The methods which do not attempt to reduce flood flows or flood levels but aim at reducing or redistributing the resulting flood losses fall under the following headings:—

1. Evacuation.
2. Zoning.
3. Changes in buildings and in their use.
4. Flood predictions and flood warnings.
5. Flood insurance.

6.8.2. One method of avoiding or reducing to a minimum the damage arising from floods is by evacuation of property located in areas which are subject to frequent and recurring floods. This method, however, presents administrative difficulties. People as a rule are unwilling to move from areas where they have been living for some length of time unless the situation becomes so dangerous that they perforce have to quit. It is however necessary in national interest to weigh up the advantage of any such evacuation against not only the expenditure involved in affording protection and relief to the flood affected people, but also the loss and damage which the people concerned sustain from such floods. This prevention of flood damage is not a form of flood control but under certain circumstances is preferable to flood control where the latter cannot be carried out adequately, because it eliminates unnecessary human suffering and

unlike flood control it entails no subsequent operation and maintenance expenditure. This method of relief should always be given consideration in order to provide an economic yardstick for other proposals.

6.8.3. Due partly to increasing population and partly to development in various spheres of national activities, there is an increasing encroachment on the waterways of the various rivers. Each river rightfully requires a certain waterway to enable it to pass its less frequent but very high floods. Because such very high floods do not at times occur for a number of years, people get tempted to encroach on this waterway, and considerable loss ensues when a very high flood occurs later. A good deal of this loss can perhaps be avoided by flood zoning whereby areas along a river are demarcated and declared as the waterway necessary for passing very high floods in the river. If expensive and easily damageable assets are not created within such zones loss will be kept within limits. Some steps have already been taken by the Central Flood Control Board in getting the State Governments to take action in demarcating flood zones on the major rivers and in preventing or dissuading people from creating valuable assets within the flood zones. This needs to be pursued.

6.8.4. Where buildings and installations cannot be removed out of the way of recurring floods, a good deal of damage can be avoided by strengthening the foundations, floors and frames of these buildings, and by removing valuable property like baggage, machinery, equipment, offices, etc. to higher floors where floods cannot cause serious damage. This is particularly applicable to towns located on river banks.

6.8.5.1. It normally takes a long time to achieve a substantial degree of flood protection, and in most cases only partial flood protection is attainable. Also there is always the possibility of such a flood coming down which would exceed the flood for which the flood protection works are designed. Therefore, while such flood protection measures are taken it is necessary to take steps to reduce damage from any unexpected flood to the minimum, by being prepared for it.

6.8.5.2. A great deal of preventable damage and suffering caused by floods is due to the following factors:—

(i) Unpreparedness.

(ii) Failure to give timely warning to people concerned, particularly in the more remote localities.

(iii) Lack of accurate information regarding the areas isolated by floods.

(iv) Inability of administrative machinery to establish immediate contact with the affected areas.

(v) Time-lag in mobilizing resources to face the situation.

A great deal of loss and suffering can be prevented by having a system of flood prediction and flood warning in the flood affected areas. Although some progress has been made in the matter of flood prediction, this still continues to be inadequate and unsatisfactory. While it is now possible for the India Meteorological Department to forecast heavy storms in the various localities, methods and procedures have not yet satisfactorily been developed to indicate the magnitude of resulting floods. Flood warning systems have, however, now been set up in most of the States where serious floods occur frequently. For instance, in Assam a number of radio stations have been established on the tributaries and along the Brahmaputra river itself to signal high flood gauges to the more important towns lower down the river. Flood warning system has also been established in other States, such as, the Punjab, U. P., Bihar, Bengal, etc. But there is considerable scope for improvement in making the warnings more useful, and this matter should receive urgent attention in the various flood affected States.

6.8.6. In certain countries flood insurance has been considered in recent years, but not yet made available. Under this scheme people living in flood affected areas are required to pay a premium commensurate with the flood danger in any particular area, and on flood damage occurring, relief is afforded to the sufferers from the insurance funds. In certain cases flood damages are also repaired from such insurance money. No such scheme has yet been considered in India. Flood insurance as a method of affording relief to flood sufferers is worthy of consideration, although, unlike fire and other forms of insurance, it applies to only a limited segment of population, and therefore, may demand such high rates of premium as to question its practicability.

CHAPTER VII

Soil Conservation

7.1. Introduction

7.1.1. Flood problems arise not so much due to excessive flood discharges in rivers as due to excessive sediment load in them. Soil conservation measures are designed to retard the speed of run-off and to minimise soil losses and consequently the sediment load in the river. Floods cannot be entirely prevented by soil conservation measures. Medium floods, however, can be moderated and thus their frequency lowered by such measures. The effect of these measures on very high floods is insignificant. But soil conservation serves, even during very high floods, the important purpose of preventing excessive loss of soil.

7.1.2. The advantages of proper land management do not restrict themselves to the diminution of flood discharge including sediment and reduction of flood damage. They increase the agricultural yields and increase the productive potential of forests and grasslands. Soil conservation is, therefore, essentially a land development programme and its effect on flood prevention is additional to the improved capability of the soil.

7.2. Role of Sound Land Management Measures

It is necessary to be clear about the role of the soil conservation operation. These can be considered under two main heads, namely, mantle of vegetation and additional land management measures.

7.2.1. *Mantle of Vegetation*

7.2.1.1. It is admitted on all hands that the ground covered with vegetation will ordinarily suffer less erosion than bare ground, and the more complete and dense the cover of vegetation the greater will be the tendency for increased infiltration and thus for reduced surface run-off. In a soil conservation programme changes and manipulation of plant cover will involve introduction of suitable vegetation on bare soil, change from erosion inducing to soil-protecting crops, introduction of suitable crop rotations, use of cover crops, prohibition of cultivation on steep slopes, mulch, green manure, fertilizers, etc. These measures come under correct land use of croplands.

7.2.1.2. In grasslands or in forests where grazing is permitted an important factor adversely affecting vegetation is over-grazing and browsing. This not only depletes the volume of growth but also reduces the plant density and brings the change to less palatable and usually less erosion-resisting species. Trampling of the soil hardens it which adversely affects the soil structure and accelerates run-off and reduces the infiltration. Cultivation of grasses, legumes and shrubs, some tree growth, and improved pasture management are vital for grasslands.

7.2.1.3. Proper management of forestlands, namely, afforestation, fellings on sustained yields basis, normal regeneration, normal increment, fire control, elimination of shifting cultivation, logging and sawing practices make for the continuation of a normal and dense forest cover in perpetuity.

7.2.2. *Additional Land Management Measures*

The additional measures include terracing, contour bunding, contour cultivation and cropping, gully plugging, check dams, outlet structures, spurs, groynes and other similar structures. These effect the run-off, infiltration and erosion, and thus indirectly affect the frequency and discharge of floods and sediment transportation; on the other hand big flood retarding reservoirs are on a different footing. Such reservoirs are built for purposes other than soil conservation, although they do reduce flood peaks and silt charge downstream. Both the measures have beneficial results as far as flood control is concerned and should be taken as complementary to each other.

7.3. Results of Research Experiments

7.3.1. Flood peak reductions resulting from storage in reservoirs and in channels can be found by usual hydrological methods. But the interrelation of soil, vegetation and water is too complex to admit of simple methods of analysis for finding peak reduction as a result of soil conservation measures, and it is necessary to have recourse to well laid-out experiments. Experimental data of any magnitude on different aspects of the problem is lacking in this country and it is, therefore, necessary to quote the results form experiments in the United States of America where a good many of these have been carried out. Conditions in India are not exactly similar to those obtaining in the United States of America but the American results are summarised below to indicate the tendencies. The research work conducted in the United States of America relates to the cultivated lands but the additional work carried out by the Forest Service in that country has corroborated the main conclusions obtained for agricultural lands. Experiments on grasslands have not been many. Comparisons between different regions are complicated by changes in soil, topography, climate, underlying rocks, slopes and rainfall, etc.

7.3.2. The following summary from a number of research units must, therefore, be studied subject to the limitations indicated above.

7.3.2.1.* *Well Vegetated Ground*—Soil losses from exposed ground are 50 to 150 times the losses from well-protected areas. The research carried out in India in different parts of the country confirms the conclusion drawn in the United States of America though the loss in every case is not as high as 50 to 150 times but is still significant.

7.3.2.2. *Terracing*—The peak rate of run-off is 50 to 60 per cent less on terraced area than on unterraced land. The terraces are important in reducing the amount of soil reaching the stream channels from the cultivated land. It is in this respect that they appear to be most effective.

7.3.2.3. *Contour Cultivation*—This kind of cultivation has a tendency to reduce the total run-off from the land so cultivated. The reduction varies from 15 to 47 per cent. The effect of contour cultivation on reduction of soil losses is greater than its effect on the run-off; the reduction may amount to 30 to 50 per cent.

7.3.2.4. *Strip Cropping*—The effect of strip cropping on run-off has been found to be conflicting. Greater effect is, however, shown in the reduction of soil losses. It must not, however, be forgotten that even in strip cropping the soil is slowly on the move but is retained within the catchment.

7.3.2.5. *Crop Rotation and Improved Management*—If crop rotation, use of mulches, manure, lime, green manure and fertilizers are combined with strip cropping the effect on infiltration capacity will be increased thus reducing the run-off as well as soil loss.

7.3.3. The effect of land use treatment under the above methods is to reduce the peak rates of run-off, total run-off and soil losses. The entire data have been derived from the research on small plots and small watersheds. The effect of these practices is more marked on storms of very short duration and of small total rainfall. But the effect decreases rapidly with the increasing duration and magnitude of storm. For purposes of flood control it may, therefore, be assumed that soil conservation practices alone would be effective in small watersheds with moderate rainfall and their effect would progressively

*The figures and conclusions under Paras 7.3.2.1. to 7.3.2.5. are taken from "Flood Control Controversy" by Leopold & Maddock.

decrease with the greater fury of the downpour spread over a long period and over large watersheds.

7.4. Faulty Land Management

7.4.1. It is interesting to know the percentage reduction in the soil losses from a fairly large and well-conserved watershed more or less comparable to Indian conditions. "Methods and Problems of Flood Control in Asia and the Far East" (Flood Control Series No. 2, ECAFE publication) mentions an experiment in the Tjijoetoeng basin in Indonesia. The area under investigation was 62,000 hectares. Elaborate investigations of the river flow during the period October 1911 — September 1912 indicated the erosion then prevailing. The catastrophic consequences following subsequent improper management, including deforestation, over-grazing and repeated burning made it desirable to repeat similar investigations during the corresponding period of 1934-35. The result of the study is as follows :—

No.	*Particulars*	*1911-12*	*1934-35*
1.	Total rainfall—10^6 cu.m.	1791·7	1941·5
	Total during wet monsoon	1550·9	1822·5
	Per cent in wet monsoon	86·0	94·0
2.	Total water run-off—10^6 cu.m.	811·6	862·6
	Total during wet monsoon	715·1	778·6
	Per cent in wet monsoon	88·0	90·0
3.	Run-off coefficient during whole year	45	46
4.	Run-off coefficient during wet monsoon	46	43
5.	Maximum silt concentration measured (gm./litre)	8·14	21·46
6.	Total silt removed—10^3 tons	821	1790
	Total during wet monsoon	804	1765
	Per cent in wet monsoon	99	99
7.	Silt removed in tons/hectare	13·2	28·9
8.	Rate of erosion in mm./year	0·9	1·9

7.4.2. It will be evident from the above figures that increased deforestation, reckless agricultural methods and pasturing after 1917 doubled the rate

of soil erosion. Soil conservation measures can, therefore, be reasonably expected to reduce soil losses significantly.

7.4.3. The land in India is owned by a vast number of individuals and Government in various departments, the former having the overwhelming part. Of the latter, the largest proportion is either owned or is under the control of the Forest Department. The Forest Department has been alive to the dangers of faulty land management in the privately-owned areas and over-grazing in other areas and for the last 30 years resolutions have been passed by various Technical Forest Conferences, drawing attention to the deteriorating conditions.

7.4.4. Faulty land management continues to be a serious menace. In relation to flood control the gravest danger is from the continuance and extension of cultivation on steep slopes without terraces. This Committee was informed of this danger most emphatically by officials of the Jammu & Kashmir Government and also those of West Bengal.

7.4.5. The practice of shifting cultivation in the hills results in increased losses of soil. For economic reasons erosion-resisting agricultural crops are not favoured and row crops like potato and maize are preferred. Soil loss from such agricultural lands is enormous on account of steep slopes and high rainfall intensity. Other malpractices are excessive fellings and looping, and unrestricted grazing and browsing by a large number of uneconomic cattle, sheep and goats. Unless restrictions are placed and grazing is controlled no measure of soil conservation can be successful.

7.5. Classification of India into Soil Conservation Zones

7.5.1. For purposes of intensification of sound land management work, India can be divided into (a) the Himalayas including the foothills, (b) the Indo-Gangetic plains excluding the Sunderbans, (c) the Deccan plateau, and (d) the Deltaic regions of the Deccan rivers and the Sunderbans.

7.5.2. The Himalayas constitute a chain of very young mountains. They are highly erodible and unstable. They receive the full blast of monsoonic downpour and their inner valleys, though outside the monsoonic belt, have heavy precipitation of snow. They yield heavy sediment through erosion and landslides, and this through ages has built up the Indo-Gangetic plain. Unless very sound land management measures are carried out in the catchment on a dam being built in these mountains the life of the reservoir will be shorter than it need be. Even where dams are not contemplated in these hills soil conservation measures are essential for the well-being and prosperity of the population in the Indo-Gangetic plain.

7.5.3. The greatest damage from flood occurs in the Indo-Gangetic plain. Though the rainfall in this plain is relatively low, the damage caused by the volume of water brought down from the hills along with enormous sediment discharge is very large. What is important is that this damage is not accentuated by faulty land management in the plains. The soil conservation in the Indo-Gangetic plains is, therefore, important though relatively not as important as in the Himalayas.

7.5.4. The Deccan plateau has no serious flood problem. Geologically it is one of the oldest regions of the earth, and river beds there are, more or less, permanent and generally in gorges.

7.5.5. The flood problems of Sunderbans and of the deltas of the Deccan rivers are problems of their own. For such deltaic areas, soil conservation measures would not be effective for solving the flood problem.

7.6. Priorities for Soil Conservation Works

The priorities for soil conservation works concerning flood control can, therefore, be fixed as under :—

(a) Catchment areas of the multi-purpose dams ;

(b) Himalayas with their foothills ;

(c) Indo-Gangetic plain ;

(d) Deccan plateau.

The Central Soil Conservation Board, it is suggested, may take note of this priority pattern. It is, however, emphasised that the greatest advantage of soil conservation measures is the retention of soil for agriculture and forests.

7.7. Organizational Set-up and Review of the Past Work

7.7.1. The Soil Conservation Board has established regional research and demonstration centres at Dehradun, Kotah, Bellary and Ootacamund where training to Officers and also to Assistants is given. The Board gives a subsidy to the States to train the sub-Assistants.

7.7.2. Most of the State Governments have formed State Soil Conservation Boards to coordinate soil conservation work effectively and to initiate suitable legislation for better land use planning. In certain States the actual investigations, planning, designing and execution of soil conservation schemes are

either under the control of the Forest Department or under the Department of Agriculture while in others there is no machinery for such work.

7.7.3. No detailed and comprehensive soil conservation schemes with particular reference to flood control have yet been evolved and executed, though there has been a long correspondence about the preparation of such schemes and a large number of meetings have been held to discuss the procedural difficulties. A numer of demonstration centres have been established in various States but not all of them relate to flood control. No single department has the responsibility with regard to soil conservation in relation to flood control, excepting Damodar Valley Corporation.

7.7.4. An important decision was taken by the Sub-Committee of Engineers at the Hirakud Seminar to recommend that an *ad hoc* provision of 2 to 5 per cent of the cost of dam should be made in the project estimates, for soil conservation measures. A small provision should also be made similarly in the maintenance estimates for the reservoir, to meet continuing expenditure on such protective measures.

7.8. Problems and Difficulties

7.8.1. The reasons for lack of progress in soil conservation measures are said to be :—

(a) Limited funds,

(b) Lack of trained personnel,

(c) Enormity of task,

(d) Lack of spectacular results in a short time.

It is somtimes held that soil conservation work entails extraordinarily heavy expenditure. According to the latest decision of the Government the Government has accepted liability of 25 per cent of expenditure (12½ p.c. by the Centre and 12½ p.c. by the State) for soil conservation measures on private lands while the remaining 75 p.c. is to be contributed by the private owners. In the final analysis the difficulty arises because of the large number of owners of land concerned and to the fact that no individual owner is under any obligation whatsoever to manage his lands in such a way as to cause minimum soil loss and to ensure the retardation of surface run-off. It must be recognised that soil conservation measures aim at a socio-economic change and unless the soil conservation work is raised to the level of a national effort appreciable progress cannot be achieved.

7.8.2. Even with funds being available lack of trained personnel has retarded the progress of work in the past. The deficiency, however, is not

insurmountable. State Governments can get the senior staff trained at the training centres set up by the Government of India. The workers of lower ranks, and their number has to be large, can also be trained in this work in large numbers without any serious difficulty. National Extension Service and Community Projects afford suitable channels for the execution of these works on a large scale, and a provision already exists for training the village level workers in this respect.

7.8.3. Apprehensions in regard to the enormity of the task are hardly justified. The task will be lightened if the general public and particularly the owners of the land are convinced of greater and higher financial returns if they adopt sound land management measures. It has been found, time and again, that the practices evolved in demonstration areas are copied by the farmers and other landowners when the beneficial results become evident.

7.8.4. Lack of spectacular results from soil conservation measures often dampens the enthusiasm of workers. The fact, however, remains that even a simple closure to grazing and browsing produces vegetal cover in two to five years and results are generally beyond expectations. If this simple closure is combined with other land management measures the results achieved are still quicker.

7.8.5. The real reasons for lack of progress in soil conservation work are apathy, lacunae in the Land Laws, Forest and Revenue Settlements, and the high incidence of grazing and browsing. Apathy can be changed to enthusiasm by publicity, establishment of demonstration areas and by better realization of the value of soil conservation measures. It may not be possible to change radically the Land Laws and the Provisions of Settlements but a workable programme is possible by the passing of an Act similar to Delhi-Ajmer-Marwara Land Development Act or the Model Act suggested by the Central Soil Conservation Board. The high incidence of grazing and browsing has to be reduced by all possible means.

7.8.6. Of the rivers that arise in these mountains some are confined to a single State and others flow in more than one State, while the third category have their origin or flow in a foreign country or countries and after traversing through such countries eventually emerge in India. The catchment area of the rivers of the first category should not present any serious administrative difficulty with regard to soil conservation measures, flowing as they do in one State. The catchment area of the second category should likewise not present a serious problem because such inter-State rivers come under the control of the different River Commissions. The last category, however, presents a

serious problem as catchment areas of such rivers cannot be protected until the foreign governments concerned agree to undertake soil conservation measures.

7.9. Suggestions for raising the Tempo of Soil Conservation Work

7.9.1. The first step would be to have the necessary powers for the evolution, execution and detailed administration of the plans. We recommend that each State must arm itself with necessary legal powers.

7.9.2. The next step should be to carry out a rapid reconnaissance survey. Such a survey would comprise land use and land capability surveys coupled with land and water conservation survey. Land should be classified according to the use to which it is being put at present and a reclassification made according to the use it should be put to. All watersheds should be arranged in the order of priority for the need of soil conservation work particularly all watersheds in the upstream reaches of a multi-purpose dam. This priority list would show the watersheds which are foci of ever-expanding erosion and would indicate in strict order of priority the watersheds which should be taken up for research and execution of schemes and plans. This rapid survey should be done by a team of officers representing the Flood Control/Irrigation, the Forest and Agricultural Departments and if necessary in collaboration with the Revenue Department.

7.9.3. The next stage would be the preparation of detailed schemes of such valleys and watersheds as require immediate treatment. A detailed scheme will have to be prepared by the three officers of the three departments afore mentioned and such schemes would show in the greatest possible detail the work to be done giving exact location and the cost.

7.9.4. Each scheme should be comprehensive for the entire catchment and work commenced in any one catchment should not be left incomplete to take up work in another catchment. Silt and discharge gauges should be installed at a point where the total discharge of the watershed in question passes, to indicate what improvements have taken place by the adoption of the soil conservation measures, as a guide for the expansion of the work in other areas. These gauges should be installed before the land management measures are adopted in order to obtain comparative figures.

7.9.5. The State Government should entrust the work of soil conservation to one single department, preferably a separate soil conservation department, thus holding the head of that department responsible for planning and execution. In the event of soil conservation service not materialising in any State in the near future, there should be proper delegation of responsibility and

authority for planning soil conservation measures. The responsibility to be effective, should be unified. As soil conservation work has various aspects such as forestry, agriculture and engineering, it would be necessary to place at the disposal of the head of the department entrusted with the planning work, suitable technical staff borrowed from other departments. This would enable him to prepare comprehensive soil conservation plans under his own general directions. In technical matters these borrowed officers might seek the advice of their respective departments, but they should be responsible to the head of the department to which they are deputed. For executing the schemes, the various aspects of work might be got executed through the departments concerned, the department responsible for planning of soil conservation measures co-ordinating the efforts of the various departments.

7.9.6. Forests, Agriculture, Flood Control and Soil Conservation are State subjects under the Constitution of India. The Centre has the responsibility for research and maintenance of training institutions for soil conservation apart from standardisation of survey techniques and desert control work. It is, therefore, in the States that the Soil Conservation organisation needs to be strengthened adequately and without delay.

CHAPTER VIII

Principles for the Fixation of Priorities of Flood Control Measures

8.1. Introduction

8.1.1. The determination of priorities among flood control measures has been receiving the attention of the Government of India in the Ministry of Irrigation and Power for some time now. In their Resolution No. DW. 14(7) 54 dated the 8th September 1954, this question figures as the first item amongst the functions of the Central Flood Control Board. The question of fixation of priorities in this Resolution has been appropriately linked up with the preparation of a comprehensive plan for flood control, and the Central Flood Control Board has been called upon "to draw up a comprehensive plan for flood control and fix priorities". Preparation of comprehensive plans and fixation of prioiities also figure in the functions of the River Commissions, State Flood Control Boards and their Technical Committees. The comprehensive plan is an overall plan involving a combination of different flood control measures required to be constructed in order to afford the maximum possible degree of flood protection in a basin in the most economical manner. Determination of priorities is an essential feature of any planned development and no comprehensive plan can be said to be complete without a broad indication of priorities.

8.1.2. Notwithstanding the considerations mentioned above, the question of fixation of priorities on the basis of comprehensive basinwise flood control plans has received little attention so far in the deliberations of the various Boards and Committees in the field of flood control, primarily because the preparation of such plans was not possible in the absence of sufficient hydraulic and other relevant data. During the last couple of years, first priority had therefore to be given to the collection of data and conducting surveys and investigations, and the construction of flood protection measures was mostly restricted to the emergent schemes. In such cases, the over-riding priority of the schemes was already known.

8.1.3. The question of priorities assumes increased importance in the economy of an under-developed country. Here the amount of money that

can be set apart for flood control works is very limited, as the various types of development programmes, all urgently required to improve the standard of living of the people, must compete for the comparatively meagre financial resources. While deciding the financial allocations, the Planning Commission has necessarily to look to the needs of a balanced development of regional economy.

8.2. General Considerations

8.2.1. The factors mentioned above make it necessary to draw up a pattern of priorities of flood control projects not only interse but also vis-a-vis other development projects according to well-defined principles suited to the prevalent conditions. In the latter case the pattern is determined by the Planning Commission, taking into account the overall needs of the country. The considerations that are relevant to determination of interse priorities are stated below.

8.2.2. *Engineering and Economic Considerations*

8.2.2.1. The degree of need for flood protection is indicated by a history of loss of life, damage to crops and other property, and frequency of such damage. In general, the protection of land that is already developed and is densely inhabited takes precedence over reclamation of unused land. As an area is built up the increase in potential hazard to life and property should be taken into account.

8.2.2.2. In according priorities to a group of projects relative cost-benefit ratio is an important consideration. Unless other considerations dictate otherwise, the more favourable the cost-benefit ratio the higher the priority that a work would deserve.

8.2.2.3. It is also important that a balance is sought in the allocation of priorities to both large and small projects provided they satisfy other criteria, so that attention is given to long-range measures as well as immediate needs. In considering the flood control projects for priority where comprehensive river basin planning for other water resources development is involved, preference should be given to works which conform more closely to the scheme of long-range development of the river system concerned.

8.2.2.4. The engineernig problems involved in the construction of a portion of the overall schemes should also be given careful consideration. For instance, a portion of the work proposed to be given priority on the basis of a maximum cost-benefit ratio may not be feasible or stable from the

engineering point of view when constructed in advance of the rest of the project. In such cases priority will have to be given to that portion of the project which must be constructed first from technical considerations.

8.2.2.5. Again, in some cases, one portion of the work may be cheaper or easier for construction than the other, but may be of temporary service only and from the long-range point of view not as good or as effective as the more costly one. In such cases, if funds are not available for constructing the more costly part of the project, giving greater or long-range benefit, priority may have to be given to the less costly portion though the benefit from it may be only temporary. Sometimes, a combination of both the temporary one to take care of the short future period, to be followed by the implementation of the more permanent method may be the best in consideration of the needs of the region and the financial resources of the country.

8.2.3. *Commencement and Rate of Accrual of Benefits*

8.2.3.1. Some types of flood protection measures, though better than others in many ways, are relatively much longer to execute, and, therefore, the protective effects in their case appear after a much longer period. In the meantime, damage continues to occur. The question arises whether it is worth while to suffer the damage in the intervening period till such time as, say a dam is constructed or soil conservation measures are completed, or whether alternative measures not as effective in the long run but which could be carried out more quickly and easily should be adopted. The answer will depend on the magnitude of the yearly damage and the difference in the periods in which the two kinds of works can be completed.

8.2.3.2. It may be argued that the difference in the period of construction will be reduced if the construction of the dam can be speeded up. However, there is a limit to the speed of construction beyond which it is difficult to go. Moreover, it may not be possible with the country's resources of men and money to invest more or go faster with the construction of a dam beyond a certain rate. Again, whether it is the construction of a dam or the implementation of the soil conservation measures, the operational area lies in the upper reaches of the river, which in certain cases such as the Indo-Gangetic belt, may lie in a different country, thus creating international difficulties. On the whole, there can be cases where the best plan would be to carry out comparatively short-term measures such as construction of embankments, and thus provide immediate protection till difficulties of the nature mentioned above are resolved and the dam can be constructed or the soil conservation measures can be undertaken and completed.

8.2.3.3. On the Himalayan rivers, many of the favourable reservoir sites lie in Nepal, Bhutan and Sikkim. For soil conservation to be effective, it has to be concentrated in the catchment areas in these neighbouring countries. The period necessary for reconnaissance, preliminary and detailed investigations and implementation of schemes is so long that alternative short-term or economically less favourable measures in the intervening period may become justifiable.

8.2.4. *Stage of Preparation of Project Reports and Estimates*

Adequately detailed project report, estimates and plans for construction should be an important consideration in deciding priorities. No useful purpose is served in granting a high priority for financing a project which will require a long period for investigations, planning and designing.

8.2.5. *Extent of Public Cooperation*

The extent of public cooperation that would be forthcoming in the execution of a scheme can be taken as an index of the urgency of the problem and the interest of the inhabitants of the area in the scheme. Population seriously affected by floods would normally be only too ready to offer cooperation in more than one way in the construction of flood protection schemes. This cooperation can take the form of free donation of land for construction purposes or in the alternative, help to the authorities in going through the normal procedure of land acquisition quickly without any obstruction. There may be offers of voluntary labour, or willingness to accept the imposition of betterment levy or flood cess. Schemes which enlist public cooperation should receive relatively higher priority over others.

8.2.6. *Strategic Requirements, and Religious, Historical and Sentimental Considerations*

8.2.6.1. Flood control works which have a bearing on the protection of strategic installations have, obviously enough, an over-riding priority.

8.2.6.2. Then there is the category of works which are needed to protect important religious or historical monuments. The cost of such works may not be commensurate with resulting benefits. Purely economic criteria or normal principles that govern the fixation of priorities may have to be set aside in such cases.

8.3. No Single-cut and Dried Formula

The above-mentioned criteria would show that there can be no cut and dried formula or a single principle for determining the relative priority of flood

control works. There are a number of considerations of which relative significance depends on the circumstances of each case. The relative priority of different projects must be decided by taking an integrated view of all the considerations given above, the human and social aspect receiving its due emphasis.

8.4. Recommended Priority Pattern

8.4.1. The application of the above criteria to a given situation is beset with considerable difficulty. Different considerations may indicate different patterns of priority. In a Master Plan which consists of scores of individual schemes costing crores of rupees, whose implementation will have necessarily to be spread over a number of decades, it becomes difficult to determine the final pattern of priorities from an overall consideration unless it is possible to fix priorities among the criteria themselves.

8.4.2. For this purpose we recommend the following pattern of priorities :—

(1) Emergent schemes.

(2) Continuing schemes.

(3) Schemes for the protection of important urban and industrial communities.

(4) Schemes which would help in augmenting food production in the country.

(5) Schemes which combine other beneficial utilisation of waters.

8.4.3. The category of emergent schemes will cover all schemes of strategic importance. Schemes meant for the protection of religious, historical or other monuments or places to which a considerable amount of popular sentiment is attached, may also get classed under this category. Temporary emergent measures necessitated by serious threats to important urban or industrial centres which require immediate protection may also be classed under this category.

8.4.4. It is obviously desirable to complete any schemes which are already under construction. In most flood control schemes incomplete works not only put off accrual of the benefits, but also there is generally the danger of such works suffering serious damage. For this purpose the various components which form self-contained units should be regarded as separate schemes and

priority allotted only to those units on which construction has reached an advanced stage.

8.4.5. Flood control schemes intended for the protection of important urban and industrial areas normally have a high benefit-cost ratio. Also the population affected in such places is normally large. Moreover, the indirect repercussions of dislocation of life in such areas or those of the industry are serious.

8.4.6. Schemes which cater for the protection of food-growing areas have an importance of their own in view of the shortage of food in the country. Schemes which lead to greater production of food by preventing damage to crops deserve relatively higher priority.

8.4.7. Added importance is assumed by schemes which envisage other beneficial utilisatian of waters.

8.4.8. Schemes, other than emergent, for which reports, estimates and plans are not yet ready obviously have to be relegated to the lowest priority. However, these schemes when fully prepared must receive consideration for allocation of priority according to merits.

8.4.9. Except for emergent schemes, no scheme should be included in the Master Plan or otherwise taken up for construction if it does not satisfy the criterion of a favourable benefit-cost ratio.

8.5. Embankments and Reservoirs

In the opinion of the Committee, the question as to whether embankments should have precedence over dams and detention reservoirs on a river which requires a combination of both, is not one of priorities, but is really a question of the best engineering and economic solution to the problem. The real criterion here is economic, that is which of the combinations, each technically feasible and sound, would afford greater overall benefits at less cost. That, in fact, is the criterion which decides which plan has to be adopted. Once the plan has been adopted, it is then more a problem of phasing rather than of determination of priorities.

8.6. Priority of Soil Conservation vis-a-vis other Measures

Soil conservation measures are also considered, and legitimately so, long-term measures. But there is an important difference between the two most

common long-term measures, namely reservoirs and soil conservation. Although both are called long-term measures, soil conservation measures really belong to category of their own. It will not be an exaggeration to suggest that engineering measures as a whole are short-term measures in comparison to measures of soil conservation. The relative priorities which have to be accorded to engineering measures on the one hand and the non-engineering measures of soil conservation on the other, form a complex problem which is perhaps not capable of a precise solution. In the opinion of the Committee, soil conservation measures should not be relegated to the background just because their results do not become apparent as quickly as those of engineering measures.

8.7. Priority for Investigation

Before any master plans are prepared certain minimum surveys and collection of data are necessary. These obviously must have a very high priority. Once this is done, further detailed investigations have to be carried out for preparing the individual schemes. As resources may preclude the possibility of carrying out the detailed investigations of all the schemes simultaneously, interse priority has to be allotted to these various investigations. It is suggested that the same pattern of priorities should be adopted for investigations as for the execution of the schemes.

8.8. Review of Priorities

It is recommended that priorities of schemes proposed for execution during the Second Five Year Plan should be reviewed now and their appropriate priorities allocated in the light of the principles laid down above. It is also necessary to similarly fix priorities for the works contained in the master plans where already prepared and in those under preparation.

8.9. Flexibility of the Pattern of Priorities

It must be emphasized that any plan of priorities cannot be final. The needs of flood protection are likely to vary from place to place and from time to time. A rapid agricultural and urban development in a region may make flood control of that area more important in the future than it has been in the past. Our knowledge of the flood characteristics of each river liable to floods has to be brought up-to-date after every year's flood season, in the light of the problems that present themselves during that season. Economic criteria like benefit-cost ratio are likely to undergo changes on account of changes in economic trends and the occurence of unprecedented floods. The regional needs of the country

are likely to undergo changes as a result of the impact of the other development schemes. Technological concepts in the field of flood control would be progressively improving and this might warrant a change in the pattern of priorities once recommended. It is, therefore, most important that priorities recommended in comprehensive basin-wise plans should be continuously under scrutiny and should be revised and modified as necessary from time to time.

CHAPTER IX

An Analysis of Factors Responsible for a Succession of Heavy Floods in the Ganga and Brahmaputra Basins in Recent Years

9.1. Related Studies in the Past

9.1.1. The occurrence of disastrous floods in a river basin has always caused apprehensions in the popular mind that flood intensities might be on the increase and so also the resulting flood damage. From time to time, the popular apprehensions prompted scientific investigations into possible trends of flood intensities, periodical cycles, etc. But these investigations do not seem to have succeeded in allaying popular fears which continue to recur with the recurrence of floods.

9.1.2. In recent times there have been two instances of such investigations in India. One was by the U. P. Flood Committee in 1948 and the other by a sub-committee appointed specifically for this study by the North-West Rivers Commission in 1956.

9.1.3. The U. P. Flood Committee, 1948 was asked "to make a study of the past history of floods in the U.P. to find out tracts which are subject to floods every year or periodically and to discover whether there is any regular cycle". The 'Survey Sub-committee' appointed by the U. P. Flood Committee examined the following data.

River and location of site	*Period*	*Remarks*
Ganga at Raiwala	1925-50	Maximum & minimum gauges.
Ganga at Narora	1925-50	Maximum & minimum discharges.
Yamuna at Tajewala	1924-48	Maximum & minimum discharges.

River and location of site	*Period*	*Remarks*
Yamuna at Okhla	1919-49	Maximum & minimum discharges.
Ramganga at Raini	1930-48	Maximum gauges & discharges.
Sharda	1931-48	Maximum & minimum discharges.
Ghaghra at Elgin bridge	1920-49	High flood levels.
Turtipur and Inchape Rly. bridges	1920-49	High flood levels.

The Committee concluded that "a study of the past history of floods in this Pradesh does not serve our purpose much, except that it reveals that floods have occurred in the past in different reaches of the different rivers in U.P. at irregular intervals, and that the causes thereof were generally different, and further, that any attempt to discover any regular cycle of floods by correlating all these scanty and scattered observational data, is not likely to be met with much of a success".

9.1.4. The problem entrusted to the Sub-committee of the North-West Rivers Commission was to investigate "whether, in recent years, there has been a tendency for higher peak discharges in the river systems of the Punjab", and if so, whether this was "due to any special factor or combination of factors". The Sub-committee examined the rainfall data for trends and periodicities and followed it up by an analysis of the gauge and discharge data of the Ravi, the Sutlej and the Yamuna. In respect of rainfall, the Sub-committee concluded that "there is no reason to believe that the meteorological regime of the region has changed to make it a higher rainfall area or an area subjected to storms of higher intensity. It is a fact that in two or three years within the last decade, very heavy rainfall occurred at the stations in this area but such a heavy rainfall at individual stations has occurred in the distant past too". Based on an analysis of the gauge and discharge data, the Sub-committee felt that there was no indication whatsoever of any progressively increasing flood discharges; nor did the Sub-committee notice "any significant rise in the bed levels of the alluvial soil and boulder reaches of the river". The Sub-committee, in fact, concluded that "it has not been possible to find what exactly has been the reason for the sudden increases in flood discharge in recent years".

9.2. Statement of the Problem

Although having a bearing on such past studies, the question contained in the first term of reference to the High Level Committee on Floods is slightly

different from the earlier investigations in certain aspects. The present Committee has been asked to "analyse the factors responsible for a succession of heavy floods in the Ganga and the Brahmaputra basins in recent years". This would involve not merely a study of possible trends or periodicities in annual flood peaks, but a study of the characteristics associated with a succession of floods in recent years, which, in other words, means the incidence of heavy floods in two or three consecutive years, an aspect which was not investigated earlier. The present study is confined to the Ganga and the Brahmaputra basins.

9.3. Approach to the Problem

Before undertaking an analysis of the factors responsible for such succession the Committee was interested to investigate first, the existence of periodicity in the succession of heavy floods and then to undertake an analysis of factors responsible therefor. The primary parameter of interest from the viewpoint of flood havoc is the river gauge. Although flood damage is not correlated with flood gauge in any simple manner, it is, however, obvious that flood damage is more closely related to the flood gauge than to flood discharge. There are other aspects like time of occurrence, duration, etc., but as a first step, flood gauges have been analysed for trends, periodicities and possibilities of succession. Moreover, flood gauge data are more readily available than flood discharge data. If a preliminary examination revealed any priodicity of succession of heavy floods, factors like rainfall and bed variations could then be correlated.

9.4. Data Available

9.4.1. In the Ganga basin, three tributary river systems were selected for study; namely, the Yamuna, the Ghaghra and the Gandak. On each of these tributaries, three gauge observation stations were selected : one in the upper, the second in the middle and the third in the lower reach of the river. On the main stem of the Ganga, three stations were selected: one in the upper reach at Raiwala, the second at Izat Railway Bridge at Allahabad, both in U.P., and the third at Dighaghat in Bihar. On the Brahmaputra, four stations were selected for a study of the gauges, namely, Dibrugarh, Tezpur, Gauhati and Dhubri. Both the maximum and the minimum gauge data were analysed. Analysis of the minimum gauge data was intended to indicate variations in bed levels.

9.4.2. The data selected for the study is shown in table below.

Sl. No.	River	Observation site	Period of availability of data		Remarks
			Max. gauge	Min. gauge	
1.	Yamuna	(i) Paonta	1915-1956	1935-1952	N. A. signifies not available.
		(ii) Okhla	1925-1956	1945-1956	
	Ghaghra	(i) Elgin Bridge	1939-1955	N. A.	
		(ii) Inchape Rly. Bridge	1924-1955	N. A.	
3.	Gandak	(i) Bhaisalton	1947-1955	N. A.	
		(ii) Chatia	1947-1955	N. A.	
		(iii) Hajipur	1947-1953	N. A.	
4.	Ganga	(i) Raiwala	1925-1955	1921-1927	
		(ii) Izat Rly. Bridge	1924-1955	1924-1955	
		(iii) Dighaghat	1939-1955	N. A.	
5.	Brahmaputra	(i) Dibrugarh	1931-1956	1931-1956	
		(ii) Tezpur	1931-1956	1931-1956	
		(iii) Gauhati	1931-1956	1931-1956	
		(iv) Dhubri	1931-1956	1931-1956	

9.4.3. The shortest record was for seven years for the Gandak river at Chatia and the longest record for fortytwo years for the Yamuna at Paonta.

9.4.4. These rivers rise in the Himalayas. The rainfall data for their upper catchments do not exist and therefore even a broad correlation of rainfall with flood gauges becomes impossible. In this connection, the available meagre rainfall data in and near the outer periphery of the Himalayas at select stations have been studied in a general manner by the India Meteorological Department and the results of their study are given at Appendix C.

9.5. Discussion of Analysis and Results

9.5.1. In each of the river basins mentioned above, an attempt was made to answer the following five questions :—

(i) Was the maximum annual flood peak in recent years unprecedented?

(ii) What is the frequency of occurrence of high floods such as were witnessed during recent years?

(iii) How far is a succession of high floods for two or three consecutive years, as happened recently, likely to recur in future?

(iv) Is there a gradual rising tendency in the magnitude of the maximum flood peaks?

(v) In case the answers to the above questions are in the affirmative, how far are the characteristics due to a gradual rising trend of the river-beds?

Hydrographs of the Yamuna, the Ghaghra, the Gandak, the Ganga and the Brahmaputra for annual peak flood gauges, and for annual minimum gauges, for two- and three-year moving averages of annual maximum and minimum gauges and for five-year moving averages of annual maximum and minimum gauges are given in graphs 1 to 16 of Volume IV. The statistical details and the nature of the analysis done are given in Appendix D. Frequency (recurrence interval) analysis of different flood heights are shown at Figures 9 to 12. The answers to the above questions in respect of each of the river basins are discussed below.

9.5.2. *The Yamuna*

9.5.2.1. The gauges recorded at Okhla (664·7 in 1955 and 665·9 in 1956) are unprecedented. The maximum in recent years at Paonta (36·0 in 1956)* is not unprecedented but definitely represents a rare flood because it was exceeded only once in the preceding 41 years (38·0 in 1947)*.

9.5.2.2. The highest gauge ever recorded at Paonta has a recurrence interval of 51 years, while the highest during the last three years has a recurrence interval of 24 years.

9.5.2.3. A succession of high floods at Paonta is confined to 1955 and 1956 with gauge readings of 35·6 and 36·0 respectively. Such a succession in two

*The values represent only gauge readings and are not connected with the mean sea levels.

consecutive years has never occurred at Paonta before 1955. However, according to statistical analysis there is a chance of its recurrence in the future once in 216 years [Table D (iv) of Appendix D].

9.5.2.4. A succession of two years like 1955 and 1956 at Okhla has never occurred before. However, it is likely to occur in future once in 277 years [Table D (iv) of Appendix D].

9.5.2.5. Heavy floods have not occurred in three consecutive years at Paonta, because the 1954 gauge is relatively much lower in comparison to the 1955 and 1956 values.

9.5.2.6. There has, however, been a three-year succession at Okhla during 1954-56 when the maximum gauge in each year was equal to or more than R.L. 663·5. Such a succession has never occurred before but is likely to occur in future once in 555 years [Table D (iv) of Appendix D].

9.5.2.7. Both at Paonta and Okhla, the maximum flood gauges appear to show a very small rising trend in general, which is, however, insignificant from a statistical point of view.

9.5.2.8. There is no similar general rising trend in the minimum gauges at Paonta and Okhla. Therefore, even the insignificant rising trend at these two stations is not attributable to a rising trend in bed levels, but may perhaps be explained in relation to similar rainfall trends. There are no rainfall data above Paonta or Okhla for conducting an analysis.

9.5.3. *The Ghaghra, the Gandak and the Ganga*

The maximum values, either in individual years or in two or three consecutive years on the Ghaghra, the Gandak and on the main stem of the Ganga have all been exceeded before. For instance, the 1955 peak value of the Ganga at Raiwala has been exceeded 10 times in the preceding 30 years. Similarly the 1955 peak value at Dighaghat was exceeded 9 times in the preceding 16 years and that in 1955 at Izat Railway bridge near Allahabad has been exceeded 11 times in the preceding 31 years. The number of times the maximum gauge in recent years has been exceeded in the preceding years is tabulated in Table D (i) of Appendix D.

9.5.4. *The Brahmaputra*

9.5.4.1. The high flood levels in recent years in the Brahmaputra at Gauhati and Tezpur have been exceeded before. At Gauhati, the 1954 flood which is the heaviest flood in the last few years, has been exceeded 4 times in the preceding

23 years. Similarly at Tezpur, the high flood of 1954, the highest during the last few years, has been exceeded three times in the preceding 23 years.

9.5.4.2. The maximum flood peak at Dibrugarh (344·1 in 1955) is unprecedented. Although it has not occurred during the preceding 24 years, it is likely to occur in the future. The increase has been brought about by a rise of the river-bed after the earthquake of 1950, and therefore the situation does not lend itself to any statistical analysis.

9.5.4.3. The years 1954 and 1955 constitute a two-year succession of heavy floods when the gauge was equal to or more than 344·1 (1954). Such a consecutive two-year succession is unprecedented, but it is likely to recur in future once in 33 years. The 1956 gauge value has been exceeded five times in the preceding 25 years and therefore, it does not constitute a three-year succession.

9.5.5. *Summary of Peak Gauge Analysis*

9.5.5.1. In the Ganga basin, in most of the tributaries and on the main stem, the peak gauges recorded during 1954, 1955 and 1956 are not unprecedented. There have been two-year successions of heavy floods in several instances in recent years, but even such successions are not unprecedented.

9.5.5.2. There are a few exceptions to this general proposition. For instance, on the Yamuna the maximum peak during 1955 and 1956 is unprecedented, as also such a succession of two consecutive years. Data for the Kosi are not available for a period long enough to permit a similar analysis but the Kosi, like the Yamuna, might be another instance of such exception.

9.5.5.3. In the Brahmaputra basin, the peak gauges and the two-year succession at Dibrugarh and Dhubri are unprecedented. The same is not the situation at Tezpur and Gauhati. The rise in the gauges at Dibrugarh is attributable to a rise of river-bed since the earthquake of 1950.

9.5.5.4. In the Yamuna changes in bed levels have not contributed to the trends in maximum gauges, which, in themselves, are not very significant.

9.5.6. *Rainfall*

9.5.6.1. The next important factor to be investigated is rainfall. In the light of the study on gauges, rainfall analysis would be needed in the catchments of the Yamuna at Paonta and Okhla and of the Brahmaputra at Dibrugarh and Dhubri. These catchments are extremely mountainous, and there is absolutely no data for comparing the rainfall in recent years with the rainfall in the earlier years. Therefore, the rainfall analysis has to follow a

pattern of general study of the rainfall characteristics principally in the non-orographic areas where some observational network exists. The meteorological factors involved have been discussed by the Committee with the Director General of Observatories, India Meteorological Department. A brief note on the storm characteristics in the Ganga and the Brahmaputra basins furnished by that Department is at Appendix C. The specific meteorological situation that caused floods in recent years are described therein. The salient points which have a bearing on the present study and which emerge out of a consideration of the available meteorological evidence are summarised hereunder.

9.5.6.2. The storm occurrence in recent years cannot be considered unprecedented. A recent study of the storms which affected West U.P. and the Punjab in the last 50 years has shown that there had been a number of occasions in the past when rainfall of the magnitude which occurred in recent years, had occurred in many of the areas.

9.5.6.3. These statements on the meteorological factors, it should be remembered, are based on a general study of the precipitation in the plains. Their validity with reference to the flood-producing potential of catchments like the Yamuna at Paonta and the Brahmaputra at Dibrugarh cannot be taken for granted.

9.5.6.4. On the basis of available data no definite cyclic trends can be established in the monsoon and storm rainfall intensities in the Ganga and the Brahmaputra basins. It may however be mentioned that studies in certain other parts of the world, such as in Southern California where greater data, though still inadequate, have been available, a certain periodicity of 25 to 30 years in cycles of increasing trends in rainfall has been noticed.

9.5.6.5. Definite comparisons of 1954, 1955 and 1956 storm rainfall intensities with earlier values in specific river catchments cannot be made in view of the absence of the requisite data in the mountainous portion of the catchments.

9.5.7. *General Discussion*

In view of the fact that there are no discernible variations in the beds except for the upper reaches of the Brahmaputra, contributing to higher maximum gauges and that unprecedented values in certain basins undoubtedly exist, the inevitable conclusion will be that such unprecedented occurrences in flood peaks should be caused by some unprecedented storm rainfall in the specific catchments either in intensity or duration or isohyetal pattern. Although there may not be definite cyclic trends or periods of these characteristics, some abnormal features associated with the storm characteristics must

have produced the unprecedented situations. The prevalence of such abnormal features cannot be established for want of data. Nevertheless, the absence of data does not rule out the possibilities of such abnormalities which alone can account for the succession of heavy floods witnessed in cases like the Yamuna and the Brahmaputra. The unprecedented character of certain occurrences in recent years does not also rule out the possibility of their recurrence in future.

9.6. Conclusions

As a result of the examination of available meteorological and hydrological data in the Ganga and the Brahmaputra basins, the Committee arrive at the following conclusions.

9.6.1. There was no unprecedented succession of heavy floods in recent years in general in the Ganga basin in several tributary streams and also on the main stem of the Ganga. The annual peak values and two-year successions like those witnessed during recent years have, generally speaking, occurred several times before.

9.6.2. There are exceptions to this general statement, like the Yamuna at Okhla, where the peak value and two-year successions witnessed during the recent years have never been recorded before.

9.6.3. In the Brahmaputra basin, the peak values and two-year successions experienced at Dibrugarh and Dhubri in recent years are unprecedented.

9.6.4. There are no general trends of increase in either maximum or the minimum gauges. The minimum gauges at Dibrugarh, however, show an abrupt increase during the last decade, presumably because of seismic disturbances in that part of the country.

9.6.5. The heavy floods which were experienced in certain river basins in recent years are not attributable to changes in bed levels, except for the Brahmaputra in its upper reaches.

9.6.6. They can only be explained by certain unusual storm rainfall characteristics which cannot be specifically delineated in the absence of specific data.

9.6.7. In general, the Committee would like to stress that they have found no indication of general increasing trends in floods in recent years. Recent years have undoubtedly been years of heavy floods. But abnormal occurrences at infrequent intervals have always been associated with natural disasters like storms and floods, and must be expected in the future also.

9.6.8. It is emphasized that the conclusions arrived at in this chapter are based on a very meagre data and must be viewed in that light.

CHAPTER X

Organisational Aspects

10.1. Scope of Review

A review of the present organisational set-up at the State, inter-State and National levels for implementing the national flood control programme has not been specifically included within the terms of reference of this Committee. Even so, we attach considerable importance to the question of organisation, because, whatever be the policy, its soundness or otherwise in the matter of flood control, the efficacy with which such a policy and programme are implemented in pratice, depends to a great extent on the adequacy and effectiveness of the organisations set up for the purpose. It is not our intention to undertake a detailed examination of the organisational structure at various levels, but we only intend to highlight some specific features which, to our mind, have been brought to focus during the last few years of intensive flood control operations in the States and at the Centre, and to suggest certain changes for improvement.

10.2. Existing Organisational Set-up

10.2.1. *States*

10.2.1.1. Recently a welcome tendency has been noticeable in the States to allocate separate technical staff to deal with flood control problems. In the past these problems were the responsibility of personnel engaged on irrigation and other water development works. In several States, there are now Superintending Engineers solely in charge of flood control work, for example in U.P., Bihar, Bengal, etc. There are also instances where problems of flood control are receiving the whole-time attention of separate Chief Engineers. Assam and West Bengal are examples.

10.2.1.2. In order to lay down policies and to coordinate flood control efforts in the States, State Flood Control Boards have been set up and these are assisted by Technical Advisory Committees. At present there are eleven State Flood Control Boards and ten Technical Advisory Committees. The typical composition and functions of these State Flood Control Boards and of the Technical Advisory Committees are given at Appendix I.

10.2.2. *Inter-State*

At the inter-State level, there are four River Commissions ; one for the Ganga, the second for the Brahmaputra, the third for the North-West rivers and the fourth for the Central India rivers. The composition and functions of these River Commissions are given at Appendices F to H.

10.2.3. *National*

At the apex of this structure is the Central Flood Control Board which gives national direction to the flood control effort in the country. The Central Flood Control Board is assisted by the Flood Wing of the Central Water and Power Commission which acts as a technical secretariat to the Board. The composition and functions of the Board may be seen at Appendix E.

10.3. Modifications in Functions

10.3.1. The functions of the various organisations at the State, inter-State and the National levels are tabulated at Appendix J. Several of the functions are either overlapping or cannot appropriately be performed by the organisation to which these are entrusted at present. We have reviewed these functions and basing our experience upon the working of these organisations have come to the conclusion that certain changes are necessary in these functions. We, therefore, recommend that the functions of the various organisations should be modified to read as under.

10.3.2. *State Technical Advisory Committee*

(1) To examine and advise the State Flood Control Board regarding long-range outline plans and specific schemes proposed for flood control measures and their relative priorities.

(2) To give technical advice on any other connected matter referred to it by the State Flood Control Board.

(3) To examine and recommend to the State Flood Control Board arrangements and programme for carrying out surveys, investigations and collection of data for flood control work.

(4) To examine and recommend proposals for flood warning system for the State.

Functions of the Technical Advisory Committee are only advisory. and they have no executive jurisdiction. Therefore, function Nos. 4 and 6 as given at Appendix J cannot appropriately be performed by this Committee

and should be deleted. For the same reason the modifications suggested above are necessary in their other functions.

10.3.3. *State Flood Control Board*

(1) To approve the long-range plan and specific schemes for flood control measures and their priorities, recommended by the Technical Advisory Committee.

(2) To assess the flood problem in the State and to deal with questions of policy in connection with floods, flood relief and measures for flood control and protection.

(3) To consider and approve of the arrangements and programme for carrying out surveys, investigations and collection of data for flood control work.

(4) To watch the progress of implementation of the approved schemes and to issue suitable directives to the departments concerned.

(5) To approve of measures proposed for coping with emergent situation.

(6) To examine and approve of the proposals for an effective flood warning system for the State.

(7) To give such other directives to the departments concerned as may be considered necessary in regard to flood problems.

10.3.4. *River Commissions*

10.3.4.1. Most of the large rivers in the country traverse more than one State. Flood control measures planned in one State, therefore, may affect other concerned States. It is, therefore, necessary to have some inter-State organisation for each river system to deal with inter-State interests and to coordinate plans of individual States. At present this function is purported to be performed by the various River Commissions in the country. Their present functions, however, are such that not all of them can adequately or appropriately be performed by them. It is, therefore, suggested that the River Commissions should confine their activities to the following :—

(1) Examination of outline master plans of the various States pertaining to a particular river system.

(2) Resolving disputes between two or more States arising out of any proposals for flood control measures in one State,

(3) To advise the Central Flood Control Board in regard to any matter pertaining to flood control works on which there is difference of technical opinion between the State authorities and the Central Water and Power Commission.

10.3.4.2. A River Commission normally has 13 to 15 members representing, besides engineers, a number of Central Departments concerned directly or indirectly with flood control. It would perhaps be expedient and conducive to speedy disposal of matters if a sub-committee of the River Commission, consisting only of engineer-officers and having powers to coopt any other officers as necessary, deals with these references and makes suitable recommendations to be considered and ratified by the River Commission as a whole.

10.3.4.3. In the light of the above observations it is suggested that the functions of the various River Commissions may be as follows :—

(1) To examine and recommend for approval to the Central Flood Control Board, outline master plans for flood control works of the river basin concerned as prepared by the States.

(2) To advise the State governments on technical problems pertaining to flood control whenever referred to them.

(3) To advise the Central Flood Control Board in respect of flood problems on which there is difference of technical opinion between two or more States, or between the Central Water and Power Commission and the State authorities.

10.3.5. *Central Flood Control Board*

(1) To lay down the general principles and policies in connection with floods and flood control measures.

(2) To consider and approve the master plans for flood control as submitted by the States or River Commissions.

(3) To consider and approve specific schemes of flood control works submitted to them for approval.

(4) To arrange for necessary assistance in connection with investigations, planning and execution of flood control works.

10.4. Procedure for Sanction of Schemes

10.4.1. There appears to be some slight confusion in this regard in the minds of some engineer-officers in the States who deal with flood control schemes. It would, therefore, be relevant here to clarify the position.

10.4.2. Proposals for flood control measures in a State are normally initiated by the department dealing with this subject. It may, from time to time, receive directions from the State Flood Control Board in regard to general policy to be followed in the matter. Flood control schemes when thus prepared are submitted to the State Technical Advisory Committee. Schemes approved technically by this Committee are then put up before the State Flood Control Board for approval. The Secretary of the State Flood Control Board, normally the Chief Engineer of the Department concerned, then submits these schemes, where necessary, to the Central Water and Power Commission, it being the technical secretariat of the Central Flood Control Board. The Central Water and Power Commission makes the necessary recommendations to that Board through the Ministry of Irrigation and Power, who in turn consult the Ministry of Finance where necessary.

10.4.3. On a dispute arising in regard to any particular scheme the Central Flood Control Board (or the Central Water and Power Commission acting on behalf of the Board) refers the matter to the River Commission concerned. That Commission reports its findings to the Central Flood Control Board.

10.4.4. There have been instances of Chief Engineers of certain States requesting the Central Water and Power Commission to approve of certain schemes technically before the schemes are submitted to the State Flood Control Board. While it is perfectly in order to obtain technical advice or guidance of the Central Water and Power Commission in the formulation of any flood control measures in a State, it would not appear appropriate or correct to seek to obtain approval of the Central Water and Power Commission before the scheme has been approved by the State Flood Control Board.

10.4.5. There can be borderline schemes about which there can be doubt whether or not they really pertain to flood control. The Central Water and Power Commission should have the responsibility and authority in such cases to call for detailed schemes even though they may cost less than rupees ten lakhs each.

10.5. Planning Organisations in States

10.5.1. A varied degree of emphasis has been given in the various States to investigation and planning of flood control measures. In most of the States, execution of flood control schemes has received much greater importance than investigations and planning. Also in some cases this latter work has been entrusted to those employed on construction of projects and no separate establishment has been set apart for investigation, preparation and planning of

schemes. This has resulted in the preparation of individual schemes based on inadequate investigations and without an overall or long-range programme.

10.5.2. For effective, efficient and economical flood control measures it is necessary to have a comprehensive plan for the river basin. This plan should not only take a coordinated view of the various flood control schemes necessary in the basin, but should also integrate these measures with water utilisation schemes. This is a task which calls for the whole-time attention of a responsible and competent engineer, assisted by necessary staff. The actual set-up to be created for this purpose in any State will depend upon the magnitude of the work required to be dealt with in that State. What is desired to be emphasized here is that in each State, having serious flood problems requiring extensive flood control measures, there should be a separate planning unit headed preferably by a senior superintending engineer to formulate and plan the various schemes and prepare an integrated outline plan for flood control.

10.6. Organisation for Soil Conservation Work

10.6.1. This matter has been discussed in Chapter VII where it has been stressed that in each State there should be some single department, preferably a separate soil conservation department responsible for soil conservation measures. The point emphasized is that there should be unilateral responsibility for this work.

10.6.2. All soil conservation schemes, requiring Central loan assistance, should normally be submitted by the State to the Central Soil Conservation Board for vetting and approval. This Board should obtain the concurrence of other Central departments, if the cost of the scheme is to be shared by these departments.

CHAPTER XI

Summary

11.1. The Nature of Flood Problem in India

11.1.1. Flood problems in India can be categorised into three types, *viz.*,

(i) Inundation ;

(ii) Erosion of river banks ; and

(iii) Change of river course. ... para 1.1.1.

11.1.2. General characteristics of the problems are fairly well known, but effective action requires a detailed study of the problems in specific problem areas. ... para 1.1.5.

11.1.3. India is divided into four regions for purposes of flood control, namely :—

(i) North-Western Rivers System ;

(ii) Ganga River System ;

(iii) Brahmaputra River System ; and

(iv) Peninsular Rivers System. ... para 1.2.

11.1.4. In the Kashmir valley the problem is the inadequate channel capacity of the Jhelum to carry away the flood discharge. In the Punjab there is a lack of adequate drainage. ... para 1.2.2.

11.1.5. In the Ganga basin the problem is mainly that of inundation, though at places erosion and inadequate country drainage also cause damage. The Kosi causes enormous damage due to oscillating bed. In the prematurely reclaimed areas of Sunderbans, tides synchronising with high floods breach embankments and cause damage. ... para 1.2.3.

11.1.6. On the Brahmaputra and its tributaries, erosion is a major problem although serious inundation also occurs. ... para 1.2.4.

11.1.7. On the Peninsular rivers the problem is that of inundation in delta areas.

11.1.8. The difference in the nature of the problems in the Himalayan and non-Himalayan rivers is chiefly in respect of sediment load and frequency of occurrence of floods. ... para 1.3.

11.1.9. The flood problem attains seriousness only in the plains and increases generally from west to east in the sub-Himalayan plains. ... para 1.4.2.

11.1.10. Absolute or permanent immunity from flood damage is not physically attainable by known methods of flood control. Flood plain zoning, flood forecasting and warning, flood insurance and like measures are as important as physical works for mitigating the flood damage. ... para 1.5.

11.2. A Brief Resume of Past Efforts in Flood Control

11.2.1. The earliest efforts in the field of flood control were embankments for the protection of specific localities in the flood affected areas, to begin with by private agencies and later by State Governments. ... para 2.2.

11.2.2. A large number of ancient tanks in South India afford incidental flood protection. Flood protection is also one of the functions of some recent multi-purpose projects. ... para 2.3.

11.2.3. In recent years, a number of conferences and committees have studied the flood problems of some of the States. They laid stress amongst other recommendations on the necessity of collection of essential data, increasing waterway in rail and road bridges where necessary, and improving drainage of low-lying areas. ... para 2.4.3.

11.2.4. The disastrous floods of 1954 brought home the necessity of national effort and direction for effective flood control. ... para 2.5.1.

11.2.5. The work entrusted to the High Level Committee on Floods constitutes the first attempt in the country for a national review of the problem. ... para 2.5.2.

11.3. Flood Damage in India

11.3.1. Available statistical data, culled from different sources under different classified headings are presented in this Chapter. ... para 3.1.2.

11.3.2. Taking into account indirect losses also, it has been estimated that the annual national income of India would go up by about Rs. 100 crores, if there were no flood damage. ... para 3.1.5.

11.3.3. The annual per capita flood damage and the damage per acre of net area sown is the highest in Assam. ... para 3.1.9.

11.3.4. The greatest flood damage in the country since 1950 has been in the Ganga basin, and next in magnitude in the Brahmaputra valley. ... para 3.2.2.

11.3.5. The meagre available data does not warrant an inference that flood damage in India has been on the increase in recent years. ... para 3.3.3.

11.3 6. The heaviest flood damage has been in respect of agricultural crops. Next in importance comes the damage to urban and rural property, the damage to public utilities ranking third. ... para 3.4.1.

11.3.7. There is lack of precision in flood damage data, and there is scope for considerable improvement in the techniques of assessment and reporting. The fundamental need is to induce more realism in the estimates of damage. ... para 3.5.

11.3.8. For purposes of economic justification of flood control schemes, it is not necessary to collect daily and weekly information about the damage under different heads. It would be enough if there is accurate information of the annual damage for a number of years in the area proposed to be protected by individual schemes. ... para 3.6.1.

11.3.9. In future, the damage to engineering works pertaining to irrigation, power and flood control should be reported by flood control organisations of the States to the Union Ministry of Irrigation and Power and the data in possession of other State Departments to the concerned Union Ministry. It is important that the data collected in the States are depicted in forms which are of ready and adequate utility to the engineers. It is recommended that the Ministry of Home Affairs may issue instructions to the State authorities, prescribing standards of assessing damage and laying down proformas for the collection and reporting of damage. ... paras 3.7.1. and 3.7.2.

11.3.10. In the States, the department in charge of flood control work should be furnished with all the information in respect of flood damage collected by other departments. At the Centre, all the flood damage information should be made available to the Central Water and Power Commission. ... para 3.7.3.

11.4. The Place of Flood Control in the Five-Year Plans

11.4.1. With a view to reduce heavy flood damage, and to alleviate suffering of large number of persons affected, provision for flood control projects has been made in the present Five Year Plan. In addition, it has been estimated that a considerable increase in the national income would occur were it possible to prevent all flood damage. It, therefore, seems evident that flood control measures have an important place in the five-year plans and deserve the same consideration as other developmental measures. ... paras 4.1. and 4.2.

11.4.2. The Committee emphasises the urgency and importance of completing investigations, and of the preparation of comprehensive basin-wise flood control plans. These plans should fit in with plans for other water resource developments, such as irrrigation and power, to the extent possible. ... para 4.2.1.2.

11.4.3. In the multi-purpose projects, care should be taken to ensure that the flood control aspect is not allowed to lose its due importance in the operational stage. ... para 4.3.2.2.

11.4.4. In considering any plan, the flood control aspect of a multi-purpose project should be considered simultaneously with other aspects and financial allocations made for all the aspects at the same time. ... para 4.3.4.

11.5. Embankments as a Method of Flood Protection

11.5.1. The building of embankments as a means of protection against flood waters, being the direct, the cheapest, and immediately effective method has dated back from the earliest recorded history. ... para 5.1.1.

11.5.2. The earlier dykes in practically all countries were, more or less, individual or private ventures, built piecemeal and extended gradually. ... para 5.2.

11.5.3. The suitability and effectiveness of embankments as a measure of flood control has been a matter of controversy in various countries since long ago. ... para 5.3.1.

11.5.4. In India, opinions have differed from State to State and from time to time. Also there has been a conspicuous vacillation of opinions in certain States, notably Bihar and Orissa. In the past few decades, the Bengal engineers have expressed themselves against embankments but this hostility has softened in recent years. ... para 5.3.2.

11.5.5. Opinion in South India has, by and large, been in favour of embankments. ... para 5.3.7.

11.5.6. *Experience of Embankments in other Countries*

11.5.6.1. The Indus in Pakistan has been completely embanked from northern border of Sind to the sea, except where the ground is high. The construction of embankments on the Indus has accelerated the aggrading tendency of the river although it must be recognised that some aggradation would have resulted even without embankments. ... para 5.4.1.

11.5.6.2. On the Irrawaddy in Burma embankments were liberally constructed between 1860 and 1920. After the 1940 floods, the general policy was towards the removal of embankments if possible and stopping construction of further embankments in the delta. ... para 5.4.2.

11.5.6.3. Embankments have been built in China over the last 2,500 years. Embankments alone have been found neither entirely dependable nor an adequate means of flood protection and in recent times are being supplemented by other methods, like reservoirs and detention basins. ... para 5.5.2.

11.5.6.4. On the Nile in Egypt, embankments have a long history. But they did not always prove invulnerable to high floods. The situation, however, improved with the construction of the Aswan Dam in 1902. ... para 5.5.3.

11.5.6.5. Dykes on the Po in Italy have, by and large, been found successful and have afforded good protection to the areas sheltered by them. ... para 5.5.4.

11.5.6.6. In Japan, embankments, though still forming the main means of flood control, have been supplemented by other methods, such as dams, detention basins and intensive soil conservation. ... para 5.5.5.

11.5.6.7. On the Mississippi in the United States, while embankments have formed the main defence against floods, other flood control measures have been adopted to increase the degree of protection afforded. ... para 5.5.6.

11.5.7. *Effect of Embankments on Aggrading, Degrading and Poised Rivers*

11.5.7.1. The intensity and grade of silt, the discharge and the bed slope are the governing factors which go to determine whether a river is aggrading, degrading or poised. ... para 5.6.4.

11.5.7.2. The rivers of the Peninsula are, by and large, poised rivers by virtue of their ability to transport silt, and unlike Himalayan rivers do not present any serious flood problem except in the deltas. ... para 5.6.5.

11.5.7.3. Inability to transport silt causes river-bed aggradation on most Himalayan rivers, notable examples being the Brahmaputra, the Kosi and the Teesta. ... para 5.6.6.

11.5.7.4. No river has a uniform behaviour all along its length. It can be aggrading, poised or degrading in its different reaches. ... para 5.6.11.

11.5.7.5. The effect of constructing embankments on an aggrading river would be to prevent spilling of the silt-laden waters beyond the embankments. If the embankments are wide apart the aggradation may under certain circumstances get accentuated. If, however, they are close enough to develop appreciably increased velocities, a more defined channel would tend to develop, and the aggradation might tend to reduce. ... para 5.7.1.

11.5.7.6. Embankments on a degrading river or a river reach having a degrading tendency, do not have an adverse effect on the river regime. ... para 5.7.2.

11.5.7.7. Embankments on poised rivers have no adverse effect on the river-bed. Embankments constructed on long reaches of rivers would initially result in increased flood heights, which in course of years, would tend to drop down to pre-embanked flood heights. ... para 5.7.3.

11.5.7.8. When spilling is prevented by building embankments, the beneficial results of spilling like increased fertility due to deposition of silt, its land-building activity and the flushing of natural depressions are automatically precluded. ... para 5.7.4.

11.5.8. *Extension and raising of Deltas and the Effect of Embankments thereon*

11.5.8.1. The sediment load which a river carries from its catchment to the sea promotes the formation of the riverine delta. The extent of delta formation depends upon the nature and extent of the sediment load. Consequently different rivers have got different rates of delta extension. ... para 5.8.1.

11.5.8.2. With the extension of the delta, the river-course lengthens and consequently the bed of the river in the lower reaches rises and high

flood levels obtain. With the spill resulting from such higher flood levels, the silt-laden flood waters raise the neighbouring deltaic land. This process of land building is further helped by tidal inflow. ... para 5.8.3.

11.5.8.3. Embankments near the sea-face prevent land-raising activity. This, in turn, poses problems of drainage and waterlogging. ... para 5.8.4.

11.5.8.4. The premature embanking of deltaic lands would result in accentuation of the drainage and waterlogging problems and of soil salinity. ... para 5.10.1.

11.5.8.5. Where a delta is extending rapidly it would be undesirable to embank the river in the lower reaches as otherwise the rising flood levels would perpetuate the problems of drainge and waterlogging in the adjoining area. ... para 5.10.5.

11.5.9. *Embankments on the Ganga and the Brahmaputra River Systems*

11.5.9.1. Considerable moderation in the maximum flood peak is experienced in the Ganga because:—

(i) Floods in the tributaries do not generally synchronise;

(ii) There is a considerable stagger in the points of outfall of the various tributaries and in consequence in their contribution to the main river; and

(iii) There is a large channel and valley storage capacity in the main river and its tributaries. ... para 5.12.2.

11.5.9.2. The flood moderating effect of the various reservoirs recently constructed or under construction on the tributaries of the Ganga would, more or less, offset the increase in flood flows caused by the embankments already constructed or planned to be constructed in the current Five Year Plan. ... para 5.13.

11.5.9.3. The bulk of the flood discharge in the Brahmaputra is received from its catchment in the Indian territory. ... para 5.12.3.

11.5.9.4. There is not as much stagger in the incidence of floods in the various tributaries of the Brahmaputra as in the case of the tributaries of the Ganga. ... para 5.12.4.

11.5.9.5. The narrow Brahmaputra valley, with its low-lying areas filling up whenever there is heavy rainfall, affords but little flood absorption capacity, particularly as high floods in the Brahmaputra are at times prolonged. ... para 5.12.5.

11.5.9.6. The extent of the rise in flood heights as a result of embankments on the Brahmaputra cannot be calculated for want of data, but it would undoutbedly be small because of the great width of the river and the small loss of valley storage. No serious adverse effects from this small increase in flood height are anticipated if the embankments which still remain to be constructed during the Second Five Year Plan according to the proposals contained in the Outline Plan for Flood Control in Assam are permitted to be completed. ... para 5.14.

11.5.9.7. Whilst the Committee is of the opinion that the embankments already constructed and those proposed for construction during the current Plan period are not likely to have any appreciable deleterious effect, it would emphasize the desirability of making adequate and careful studies of the effects of any new proposal before its acceptance. ... para 5.16.

11.5.10. *Construction and Maintenance of Embankments*

It is of utmost importance to have satisfactory arrangements for the maintenance and repairs of embankments already constructed. The cost of such maintenance and repairs is likely to be heavy, and modifications are also likely to be required from time to time to suit changing river conditions. The financial implications of such recurring costs need careful consideration at the planning stage. ... para 5.17.

11.5.11. *Suitability of Embankments as a Method of Flood Control*

In general, embankments are a satisfactory means of flood protection when properly designed, satisfactorily executed and adequately maintained in locations where construction of embankments is technically indicated but a suitable combination of this method with other methods such as storage dams, detention basins, etc. is often more efficient and desirable. ... para 5.18.

11.6. Other Methods of Controlling Floods or Reducing Flood Losses

11.6.1. Methods of reducing flood losses fall into two categories; first, those aiming at physical control over floods, and second, those aiming at reducing or redistributing the resulting flood damage. ... para 6.1.1.

11.6.2. Methods of physical control over floods besides embankments are storage reservoirs, detention basins, channel improvements, diversions, raising habitations above flood levels and watershed improvements.

... para **6.1.2.**

11.6.3. Reservoirs bring about flood moderation by withholding peak flood flows and releasing the stored water later in regulated quantities. Reservoirs intended only for flood control are generally at an economic disadvantage. Reservoirs for power and other benefits must have separate storage reservation for flood control, if they have to serve the purpose of flood control also. When there is no such separate reservation, they may absorb early floods but will not be effective in the later part of the flood season. Flood control reservoirs are effective means of moderating floods, but are economical only when combined with other methods. All storage reservoirs however have a limited life. ... para **6.2.**

11.6.4. Natural depressions on either side of river afford a certain degree of flood moderation. The capacity of such depressions can be increased appreciably for moderating floods by building an embankment around them with regulating devices. There are no large detention basins in India that can bring about appreciable flood moderation in rivers of the size of the Ganga or of the Brahmaputra. This method can, however, find application in a number of small rivers like the tributaries of the Ganga in North Bihar or of the Brahmaputra. ... para **6.3.**

11.6.5. Channel improvements consist of improving the cross-section, channel clearance, straightening the channel, cut-offs and lining. The Jhelum in Kashmir, downstream of Wullar is an instance where channel enlargement is required for easing the flood situation in the Kashmir valley. Channel clearance can, in certain cases, lead to permanent improvement in the flow conditions in the river. Straightening the channel and the use of cut-offs have been tried in various countries. Such possibilities exist even in India which, however, would require careful study and experimentation. Lining river channels for improvement of flow conditions has not been done in India but has been tried in other countries having plentiful resources.

... para **6.4.**

11.6.6. The Lower Mississippi offers an instance of river diversion of considerable magnitude. In India, diversion has been resorted to in the case of rivers like the Jhelum, the Mahanadi and the Brahmini. River diversion is a method which should be kept in view in preparing flood control plans for any river system. ... para **6.5.**

11.6.7. Where it is not economically possible to preclude floods in certain areas, raising of habitations or other important places is resorted to, to prevent damage to property and inconvenience to inhabitants. This method has been successfully adopted in East U.P. and can be used in Lower Bengal and other similar situations. ... para 6.6.

11.6.8. Extensive and intensive land management methods in river catchments have important effect on flood control by virtue of sediment reduction. ... para 6.7.

11.6.9. Methods of reducing and distributing flood losses other than physical works are evacuation, zoning, changes in buildings and in their use, flood warning and flood insurance. Evacuation would be indicated when no known method of flood control proves feasible. ... para 6.8.

11.7. Soil Conservation

11.7.1. Control over excessive sediment is important in seeking control over floods. Soil conservation is essentially a land development measure, but, if carried out extensively in catchments, it also helps in reducing the sediment load in rivers, and this tends to make them less liable to change their course or to erode their banks. The effect of soil conservation measures on high flood discharge is not marked, but medium floods are moderated and their frequency reduced. ... para 7.1.

11.7.2. Soil conservation measures comprise :—

(i) Maintaining a mantle of vegetation over the land during periods of heavy precipitation to reduce soil erosion ; and

(ii) Additional measures such as terracing, contour bunding, contour cultivation, gully plugging, check dams, etc. ... para 7.2.

11.7.3. Research and experiments carried out indicate that the effect of soil conservation measures decreases rapidly with increase in the fury of the storm, in the period of rainfall and in the size of the catchment. ... para 7.3.

11.7.4. Priorities for soil conservation works relative to flood control can be fixed as under :—

(i) Catchment areas of the multi-purpose dams ;

(ii) Himalayas with their foothills ;

(iii) Indo-Gangetic plains ; and

(iv) Deccan plateau. ... para 7.5.

11.7.5. The Deccan plateau has no serious flood problems and soil conservation measures are not indicated for solving the flood problems in the deltaic areas. ... para 7.6.

11.7.6. The Central Soil Conservation Board and the State Soil Conservation Boards have been formed to coordinate and control soil conservation measures. No detailed or comprehensive soil conservation schemes with reference to flood control have, however, yet been evolved, as no single department is responsible for this work. ... para 7.7.

11.7.7. The difficulties in implementing soil conservation measures arise because there is a large number of owners of land, who are under no obligation to manage the land in a manner that would ensure soil conservation. Lack of trained personnel and lacunae in land laws have so far retarded the progress of works. Training programmes at various levels must be intensified and suitable laws enacted. Grazing and browsing must be controlled. Difficulties are likely to present themselves in carrying out soil conservation measures in the case of rivers with catchments in foreign territories. ... para 7.8.

11.7.8. In order to increase the tempo of soil conservation works relating to flood control, watersheds should be arranged in the order of priorities and detailed schemes should be prepared for such works and watersheds which require immediate treatment. Work commenced in a catchment should not be left incomplete to take up work in other catchments. ... para 7.9.

11.8. Principles for the Fixation of Priorities of Flood Control Measures

11.8.1. Determination of priorities is an essential feature of any planned development, particularly in the economy of an under-developed country in view of the limited financial resources and competing claims of different developmental schemes for a share. ... para 8.1.

11.8.2. The protection of land that is already developed and is densely inhabited takes precedence over reclamation of unused land. In according priorities amongst a number of projects, relative cost-benefit ratio is an important consideration. A balance should be sought between large and small projects, provided they satisfy other requisite criteria, so that attention is simultaneously given to long-range measures as well as to immediate need. ... para 8.2.2.

11.8.3. Some flood protection measures, although more effective, take relatively much longer time to execute. In such cases priority may have to be

given to less effective short-term measures affording immediate protection, depending upon the magnitude of the yearly damage and the difference in the period of construction. .. para 8.2.3.

11.8.4. Purely economic criteria or normal principles governing the fixation of priorities have to be set aside in considering schemes of strategic importance or for the protection of important religious or historical monuments. ... para 8.2.6.

11.8.5. Priorities must be decided by taking an integrated view of the various considerations involved, the human and social aspect receiving its due emphasis. The following order of priorities in general is recommended:—

(1) Emergent schemes.

(2) Continuing schemes.

(3) Schemes for the protection of important urban and industrial communities.

(4) Schemes which would help in augmenting food production in the country.

(5) Schemes which combine other beneficial utilisation of waters.

... paras 8.3. and 8.4.

11.8.6. In the matter of investigations necessary for the preparation of master plans, the same pattern of priorities should be adopted as for the execution of the schemes. ... para 8.7.

11.8.7. The priorities for schemes proposed for execution during the Second Five Year Plan should be reviewed now and their appropriate priorities allocated in the light of the principles herein enunciated. Similarly, priorities must be fixed for the works contained in the master plans already prepared or under preparation. .. para 8.8.

11.8.8. Priorities recommended in comprehensive basinwise plans should be reviewed from time to time and modified as necessary. ... para 8.9.

11.9. An Analysis of Factors responsible for a Succession of Heavy Floods in the Ganga and Brahmaputra basins in recent years

11.9.1. The three-year succession of heavy floods in the Ganga basin (1954-56) was in general not unprecedented, as similar successions have occurred more than once in the past. ... para 9.6.1.

11.9.2. On the Brahmaputra the flood levels do not indicate any increasing trend in general. At Dibrugarh, however, both the maximum and the minimum levels have shown an abrupt increase since the earthquake of 1950. ... para 9.6.4.

11.9.3. The Committee have found no indication of general increasing trends in floods in recent years. These have undoubtedly been years of heavy floods. But abnormal occurrences at infrequent intervals have always been associated with natural phenomena like heavy storms and must be expected in future also. ... para 9.6.7.

11.10. Organizational Aspects

11.10.1. The existing organizational set-up at the State, inter-State and National levels is described in this chapter. ... para 10.2.

11.10.2. Several of the functions cannot appropriately be performed by the organisations to which they are entrusted at present and in some cases they are overlapping. Modifications are suggested in the functions of the State Technical Advisory Committees, State Flood Control Boards, River Commissions and the Central Flood Control Board. ... para 10.3.

11.10.3. The procedure for processing and sanctioning the flood control schemes is clarified. ... para 10.4.

11.10.4. In each State having serious flood problems requiring extensive flood control measures, there should be a separate planning unit, headed preferably by a senior Superintending Engineer, to formulate the various schemes and to prepare an integrated outline plan. ... para 10.5.

11.10.5. There should be unified responsibility for soil conservation at the State level. All soil conservation schemes requiring Central loan assistance should normally be submitted by the State to the Central Soil Conservation Board for vetting and approval. This Board should obtain the concurrence of other Central departments, if the cost of the schemes is to be shared with them. ... para 10.6.

CHAPTER XII

Recommendations

12.1. Absolute or permanent immunity from flood damage is not physically attainable by known methods of flood control. Flood plain zoning, flood forecasting and warning, and like measures should therefore be given due importance, particularly as these do not require large capital investment. ... para 1.5.

12.2. There is lack of precision in flood damage data. The techniques of assessment and reporting flood damage should be improved to make the estimates of damage realistic. ... para 3.5.

12.3. For purposes of economic justification of flood control schemes, it is not necessary to collect daily and weekly information about flood damage, and this might be discontinued. The annual flood damage data under various heads should, however, continue to be collected and reported. ... para 3.6.

12.4. Damage to engineering works pertaining to irrigation, power, and flood control should be reported by Flood Control Organizations of the States to the Union Ministry of Irrigation & Power, and the data collected by other State Departments to the concerned Union Ministry. Copy of all this information should be furnished by the various State Departments to the Flood Control Department of the State. At the Centre all the flood damage information should be made available to the Central Water and Power Commission, by the various Ministries. ... para 3.7.

12.5. The Ministry of Home Affairs, in consultation with other concerned Ministries, may prescribe standards for assessing damage and lay down proformas for collection and reporting of relevant data. ... para 3.7.

12.6. Flood control schemes should fit in with plans for other water resource developments such as irrigation, power, domestic water supply, etc. to the extent feasible. ... para 4.2.

12.7. In multi-purpose projects, care should be taken to ensure that the flood control aspect is not allowed to lose its due importance in the operational stage. ... para 4.3.

12.8. In considering future plans, the flood control aspect of a multi-purpose project should be considered simlutaneously with other aspects and financial allocations made for all the aspects at the same time. ... para 4.3.

12.9. Where a delta is extending rapidly, the lower reaches of the river should not be embanked as otherwise the rising flood levels would perpetuate the problems of drainage and waterlogging in the adjoining areas. Similarly premature embanking of freshly formed lands at the deltas must be avoided.
... para 5.10.

12.10. The flood-moderating effect of the various reservoirs recently constructed or under construction on the tributaries of the Ganga would, more or less, offset any increase in flood peaks caused by the embankments already constructed or planned to be constructed in the current Five Year Plan.

The extent of rise in the flood heights as a result of embankments on the Brahmaputra already constructed or planned to be constructed during the current Five Year Plan would be small because of the great width of the river and the small valley storage as compared with the large channel storage.

Embankments as proposed on the Ganga and the Brahmaputra river systems for construction during the current Plan period may, therefore, be completed without apprehension of adverse effects.
... paras 5.12, 5.14 and 5.16.

12.11. Proposals for constructing flood embankments which State Governments may have in view for inclusion in the third and subsequent five-year plans, should be studied in detail to determine their effect on the river basin before these schemes are accepted for inclusion in the plan. ... para 5.16.

12.12. In general, embankments are satisfactory means of flood protection when properly designed, satisfactorily executed and adequately maintained in localities where the construction of embankments is technically indicated but a suitable combination of this method with other methods such as storage dams, detention basins, etc., is usually more efficient and should be adopted as resources permit. ... para 5.18.

12.13. When it is not economically possible to preclude floods in certain areas, raising of habitations or other important places may be resorted to in order to prevent damage to property and inconvenience to inhabitants. ... para 6.6.

12.14. Priorities for soil conservation work relative to flood control should be as under :—

(i) Catchment areas of the multi-purpose dams ;
(ii) Himalayas with their foothills ;
(iii) Indo-Gangetic plain ; and
(iv) Deccan plateau. ... para 7.5.

12.15. In order to increase the tempo of soil conservation work relating to flood control, watersheds should be arranged in order of priorities and detailed schemes should be prepared for such works which require immediate treatment. Work commenced in a catchment should not be left incomplete to take up work in other catchments. ... para 7.9.

12.16. Soil Conservation Organization in the States should be strengthened. There should be a unified authority and responsibility for soil conservation work. Also the State Governments should arm themselves with the necessary legal authority for evolution and execution of soil conservation schemes. .. para 7.9.

12.17. Priorities amongst flood control schemes must be decided by taking an integrated view of the various considerations involved, the human and social aspect receiving its due emphasis. The following order of priorities in general is recommended :

(i) Emergent schemes ;

(ii) Continuing schemes ;

(iii) Schemes for the protection of important urban and industrial communities ;

(iv) Schemes which would help in augmenting food production in the country ;

(v) Schemes which combine other beneficial utilisation of waters. ... paras 8.3. and 8.4.

12.18. In the matter of investigations necessary for the preparation of master plans, the same pattern of priorities should be adopted as for the execution of the schemes. ... para 8.7.

12.19. The priorities for schemes proposed for execution during the current Plan, as also those in the master plans already prepared, should be reviewed and appropriate priorities reallocated. ... para 8.8.

12.20. Priorities should be reviewed from time to time as the factors which go to determine priorities change with time. ... para 8.9.

12.21. Several of the functions allotted to the State Technical Advisory Committees, State Flood Control Boards, River Commissions and the Central Flood Control Board are overlapping. Some of these cannot appropriately be performed by the Organization to which they are entrusted at present.

Modifications in these functions have been suggested in the Report and may be adopted. ... para 10.3.

12.22. In each State, having serious flood problems, requiring extensive flood control measures, there should be a separate Planning Unit, headed preferably by a senior Superintending Engineer to formulate the various schemes and to prepare an integrated Outline Plan. ... para 10.5.

12.23. All soil conservation schemes requiring Central loan assistance should normally be submitted by the States to the Central Soil Conservation Board for vetting and approval. That Board should obtain the concurrence of other Central Departments if the cost of the schemes is to be shared with them. ... para 10.6.

A. C. MITRA *Chairman*	BALWANT SINGH NAG	R. D. DHIR

Statement of Mr. H. E. Hedger

Chief Engineer, Los Angeles County Flood Control District
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1.1. I wish to take the this opportunity of expressing the pleasure and honour it has given me to join with the Members of the High Level Committee on Floods in reviewing the Report you have so ably prepared and to consult and deliberate with you in reaching conclusions as to the principles and procedures for a future flood control program to be recommended in the Report. The friendly reception afforded me and the many courtesies extended by the Members of the Committee are acknowledged with deep appreciation.

1.2. Due to previous unfamiliarity with flood causes and conditions in India and the fact that my visit here has been of too short a duration to allay this shortcoming, it of course has not been possible for me to have personal knowledge of the factual observations made in the Report, but they have been so clearly presented that I have had no difficulty in analysing them for comparison with flood hazards and problems in the United States with which I am quite familiar. It is most gratifying to me to state that the causes of floods and conditions resulting therefrom as described in the Report are quite in keeping with similar phenomena in Sourthern California and other parts of the United States that I have observed in nearly forty years of flood control and conservation experience. It is reassuring to know that the causes of floods and the principles and procedures for their restraint, are so universally understood and applied as to create little difference in opinion on these subjects between the flood control engineers of widely separated countries. It is of course true that the application of such principles and selection of procedures often leads to less agreement, even among the engineers of a local area but, if not carried too far, such differences can be stimulating and beneficial.

1.3. For the reasons mentioned, the following remarks will be confined to the general aspects of the flood problem in India and to the necessities of a sound engineering approach to its treatment, as I see them. Certainly your Committee has been called upon to report on this subject at a most propituous time, inasmuch as the need for a national flood control program has but recently developed and a wonderful opportunity exists for getting it started on a sound basis.

1.4. The early chapters of the Report review the history of flood relief measures in several other parts of the world as well as in India, and throughout this record, will be found instances of failures of such measures in times of great flood with resultant severe loss of life and damage to property as well as loss of public confidence. Although on rare occasions great floods occur which may be considered as beyond the normal ability of man-made structures to abate, it is my belief that by far the greater number of failures have occurred due to inadequate estimates of the peak flows that may occasionally be exprienced or to unsatisfactory design or construction of relief measures. Unless those responsible for providing flood reduction facilities and those who rely upon them for safety, are willing to accept something less as a calculated risk, then flood protection should be planned and provided on the basis of handling the maximum flows to be expected over a reasonably long period of time.

2. Sound Hydrology

2.1. The first requirement for dependable program of flood relief measures is therefore the accumulation and utilization of adequte data for estimating maximum flood flows on a long-range basis. I find that such a program has been planned in India but no doubt many years will pass before the data it produces will reliably indicate the greatest floods to be expected.

2.2. In the meantime reliance must be placed upon the records now available for preparing estimates of maximum flood flows. Since usually such records are of but short duration, it is very important that the best use possible be made of all basic data that can be found, and that estimates of flow based on one set of data be checked by another. Rainfall records are commonly of greater length and accuracy than river flow records, and, through application of modern methods of calculating hydrographs, will generally produce sounder long-range estimates of maximum river flow, particularly in smaller watersheds, than do flow measurements.

2.3. Furthermore, the use of hydrographs prepared by rational runoff methods based on rainfall data is well adopted to consistency in estimating maximum flows for different river systems. Estimates of maximum flow based on records of short duration of dubious accuracy may lead to planning of flood protection on one river system for a much rarer flood occurrence than on another.

2.4. Adoption and use of sound methods of hydrology, if adequately implemented by staff and facilities, will in due time result in determination of maximum flood flows to be expected on a reasonably long-range basis at

critical points along each of the rivers needing flood control treatment. This objective is absolutely essential if a rational flood control program is to be planned in a reliable and uniform manner. I attach hereto as an appendix a description of a rather complex but quite accurate method used by my organization. A much more simple adaption may be of assistance here.

2.5. It will of course require considerable time to complete such extensive studies. Many pressing needs will call for action with no delay in the meantime. Priority in determination of maximum flows can be given in such cases through preparation of computed hydrographs provided criteria is established as to how great a storm (usually determined in order of frequency of occurrence) is to be planned for. This criteria must be established before uniform comprehensive planning can be initiated, and may be called a Comprehensive Plan Standard design flood. This criteria should be the subject of extensive study as it is concerned with such matter as economics, the national potential for annual financing of flood control works, social and political effects of flood damage, physical limitations of flood control structures, and other considerations, but in any event the degree of storm to be provided for should be as great as can be afforded. In the area of the United States from which I come the policy has been adopted of planning for the greatest storm, both in intensity and duration of rainfall, to be expected in a 50-year period, occurring on a saturated watershed, as representing the maximum degree of protection that can reasonably be afforded. Once such criteria is adopted the way is paved for uniformly applying the hydrograph method of calculating maximum flows wherever rainfall intensity duration data of reasonable length is available or can be correlated.

2.6. In the event that installation of flood protection measures cannot await the preparation of sound estimates of maximum flows, or that economics will not warrant installation of maximum protection, then all concerned, particularly those depending on such measures for protection, must accept the fact that they are not based on sound engineering hydrology and may prove inadequate for their intended purpose. Many structures, particularly embankments, have been built on this basis and accepted on the assumption that partial protection is better than none, but unless this is understood by all, a false sense of security will be created among those expecting protection.

2.7. The hydrological data to be accumulated under the current program will provide essential information concerning rainfall intensity and duration, continuous records of river flow, sedimentation data, temperature and other meteorological readings, evaporation records, etc., all of which is essential to sound hydrology. Undoubtedly this program will need amplification as time

goes on and it will most certainly require the full support of Government financing and public cooperation to be effective.

3. Sound Planning of Flood Control Projects

3.1. The first requirement for sound planning of flood protection works will be met when sound methods of hydrology have been applied and the maximum flood flow estimates so determined are available for critical points on the river system to be studied.

3.2. The next requirement will be the consideration of alternate methods of control or protection that appear reasonable of attainment. It is probable that a large river system will require several methods of treatment to meet varying conditions along its course, and no doubt every method now in use will find application somewhere in India.

3.3. Such methods to be considered will include the possible use of flood control reservoirs ; of offstream detention storage, of by-pass floodways ; of river embankments and spurs ; of erosion-reduction measures, including afforestation, and other similar measures as the particular circumstances of each river to be studied warrant. Sound planning will also require that each alternate be subjected to economic analysis for the purpose of determining project justification and to assist in selection of the best alternate.

3.4. Nearly all flood control or flood protection projects are expensive when treated on a comprehensive and long-range basis, and it is firmly suggested that sound project planning must include in all cases, consideration of the possibility of restrictive zoning or otherwise setting aside the flood plain of the river for only such use as can withstand flooding of varying frequency. Since this possibility will involve the removal or reconstruction of habitations, the loss of crops damaged or destroyed during periods of flood ; damage to public utilities ; loss of land caused by bank erosion or by detrital spill ; public inconvenience and other adverse factors, these too must be evaluated to determine the cost of setting aside the flood plain for flood usage.

3.5. It is quite possible that removal of flood plains from human habitation may in many cases prove to be the most economical course and also the quickest method of reducing flood losses, particularly loss of life. Such cases would demand strong proof of need before other reasons could justify an alternate and more expensive form of flood relief.

3.6. It is probable, however, that solution of the flood problem on the larger river systems will necessitate a combination of several of the various methods mentioned. In any event, the effect of any proposed flood control

or protection measure, or combination of measures, on all reaches of the river system, should be determined and accepted before a plan is adopted or construction of any component part is undertaken.

4. Embankments

4.1. Particular attention has been given by the Committee to the method providing flood protection through the planning and construction of embankments and a consensus of the discussions held on this subject is included in the Report. This Section of the Report stresses the disadvantages, as well as the benefits, that can be expected to result from the construction of embankments.

4.2. It is my view that if a flood control or protection system is to be soundly planned, all parts of the system should be adequately designed, constructed to meet the requirements of the maximum flood flow the system is intended to handle. Embankments should be designed and constructed to meet the same criteria as to maximum flow, relief from overtopping, stability and other factors of safety as other structures must, and thereafter must be maintained in this condition. On such a basis, the use of embankments constitutes a proper and useful form of flood protection. Any lesser treatment will in the event of a design flood cause overtopping and probable breaching with resultant potential loss of life and property.

4.3. As stated elsewhere, emergency conditions and public demand will probably at times necessitate installation of embankments without allowance for proper study and design, and perhaps be warranted by the circumstances, but the possible inadequacy of such installations to withstand great floods must be recognized and accepted. They should be classed and treated as temporary structures until their design can be reviewed and inadequacies corrected, if found to exist.

4.4. Installation of embankments along any reach of a river will nearly always affect the flow of the river on other reaches downstream, and to some extent upstream. Sound engineering will always take this into account and will include the anticipated damages or benefits in the economic evalution of the project. Methods of hydrology which result in computation of hydrographs of flood flows at critical points are especially well suited to determination of the effect of reduction in valley storage attributable to proposed embankments upon maximum flood discharges on downstream reaches.

4.5. Proper planning of proposed embankments for both sides of a river channel usually require a study of alternate locations or spacing to determine

the most economic proposal and minimum influence on other reaches of the river as well as for comparison with the economics and other effects of zoning or otherwise prohibiting use of the flood plain for habitation.

5. Sediment and Debris

5.1. By and large, the occurrence of sediment and debris in rivers everywhere is the consequence of land erosion caused by natural forces that are unceasing as to recurrence. Corrective measures that have been developed include reforestation ; modern farm practices, such as contour cultivation, terracing, selected crops, etc ; measures to stabilize eroding stream beds, hillsides and landslides, usually through construction of small masonry or concrete dams or retaining walls, construction of debris basins or traps at the mouths of small watersheds, as in the Southern California area in the United States ; and other similar methods.

5.2. The structural measures developed so far are usually very expensive, and, when applied to sizeable watersheds, become prohibitive in cost. Such measures, even when ecconomically warranted, usually reduce, but do not overcome, the movement of debris or sediment downstream.

5.3. There is little indication that such measures can be very effective in solving the sedimentation problems here, particularly on the larger rivers, although it is good practice to apply them, particularly the less expensive measures, wherever they are suited and economically justified. The fact that erosion and resultant sedimentation will continue virtually unabated in the foreseeable future must be accepted and this condition taken into account in the planning of river projects. It therefore becomes important to learn all that is possible concerning the erosive nature of the watershed and the sediment-carrying capacity of each river having this problem so that future sedimentation characteristics can be provided for in planning its control or protection. The collection of adequate sedimentation data on a regular and continuing basis constitutes a very important phase of the hydrological program heretofore discussed.

5.4. While the gravity of problems caused by aggrading of river-beds cannot be discounted and this must always be considered in sound planning of a project, it does not necessarily follow that all river development should be suspended because of the certainty of river-bed aggradation over a long period of time. Sedimentation problems such as siltation of reservoirs, aggradation of river beds and delta extensions, which seem sure to develop in a century or more may well be alleviated over such a long period of time by other

developments which tend to stabilize the river-bed or reduce the present rate of sedimentation. Also, future generations may find better means of erosion control than are today available.

6. Priorities

6.1. The establishment of priorities for planning and for financing of flood control projects becomes necessary when the demand exceeds the available rate of financing. This problem is common in the United States and such priorities are usually developed and recommended in that country by the flood control engineers and thereafter acted upon by the appropriate legislative body. Such priorities may properly be established by the application of sound judgement and experience in the field of flood control to the following considerations:

1. The need for flood protection as demonstrated by a history of loss of life, damage to crops and other property and frequency of occurrence. As an area is built up, potential as well as existing hazards to life and property must also be taken into account.

2. The magnitude of the problem as determined by the size of the population and property valuations affected. In general, the protection of land that is already developed and densely inhabited takes precedence over the reclamation of unused land. The need for national defense or other governmental purpose may substitute for this form of justification.

3. The readiness of plans for construction. No useful purpose is served in granting a high priority for the financing of projects which will require a long period for planning and design. The time required for these purposes is usually from one to three years, and often longer, depending on the availability of basic design data and experienced personnel, backlog of other project planning, etc.

4. The estimated cost of the project. A balance must usually be sought in the allocation of priorities to both large and small projects, provided they meet other criteria, so that attention is given to long-range measures as well as to immediate needs.

5. The amount of local cooperation to be extended. This factor is particularly important when reclamation of undeveloped lands is involved.

6. The degree of conformity with long-range development of the river system concerned. This factor should apply to comprehensive river basin planning for other water resources development as well as for flood control.

7. Relative cost-benefit ratios of the various projects to be considered. This factor is useful in selecting priorities for a group of projects which are of about equal standing as to other reasons for justification.

6.2. Political considerations receive attention in the legislative process and do not enter into engineering consideration unless required by statute.

6.3. Priorities are subject to change due to such events as major floods in new areas, rapid population increase in various parts of the country, or new proposals for multi purpose water resource development. It is therefore necessary that they be reviewed whenever a financing or planning program is prepared.

7. Organisation

7.1. The organisation of governmental agencies to most efficiently handle the preparation and carrying out of flood control measures involves matters of internal policy which are not appropriate subjects for outside advice, and while the chapter devoted to this subject has been reviewed with great interest no comment is offered except the following statement of principles usually found necessary if good progress is to be maintained on a large flood control program. These principles call for the pinpointing of responsibility upon the head of the agency set up to carry out such a program whether it be at national, State or other level, and the granting to him of full means and authority to perform or obtain the prompt performance of the functions necessary to get the job done. The plans of such an agency should be co-ordinated with other water resources development, and for this purpose it should have to submit its project plans to other agencies dealing with water resources and to solicit and consider their comments.

7.2. The functions usually required for the development of a flood control program include :

Accumulation and analysis of hydrologic data.

Accumulation and analysis of statistical and economic data relative to flood damages.

Comprehensive planning of a long-range program of sound flood control measures, checked as to economic justification.

Establishment of priorities for such measures.

Detailed investigation and design of individual projects, requiring surveys, field tests, geological exploration, etc.

Determination of lands needed and acquisition thereof.

Legal Services.

Construction of projects.

Maintenance and operation of projects.

Incidental services such as adequate field communications, hydraulic model studies, physical and chemical testing ; means for receiving and handling complaints, administrative and clerical functions are also usually involved.

7.3. All of these functions are important, but for an effective program of construction it is particularly necessary that land acquisition causes no delay. The power of eminent domain with legislative authority to obtain immediate possession of needed lands is vital to a large-scale program of construction.

7.4. An otherwise perfect organisation is helpless without financial support for its staff and facilities and for construction, maintenance and operation of its projects. Intimate acquaintanceship with these needs on the part of top government officials is essential for this purpose. It usually works well to organise a flood control department on purely technical lines under the leadership of a qualified Chief Engineer who is responsible to a flood control board of elected or top level appointive officials. Under this type of organisation, a flood control agency can devote its full and prompt attention to the technical duties of planning, designing, constructing and maintaining projects under the guidance of policies promulgated in the public interest by the top-level board.

8. Financing

8.1. A prerequisite to the success of any sizeable long-range plan of flood control is an orderly procedure for its financing. Historically, flood control projects have been financed and built by individuals, by groups of property

owners, by cities, districts, state or by national governments, the tendency inclining toward governmental responsibility as the number of people affected and the magnitude and cost of protective measures has increased. Usually all or most of these agencies have some degree of interest and concern in the protection to be afforded and participate in the project accordingly. In the Union States, the problem of financing major flood control works that are economically justified (*i.e.*, benefits exceed costs on an average annual basis) has been resolved by allocation of construction costs to the national agency and of land acquisition and maintenance costs to the local agency. Smaller projects are generally the responsibility of a local agency, state, country or municipality. A reasonable amount of local contribution is usually desirable to keep the demand for national participation within reasonable limits.

8.2. Regardless of any sharing or division of costs it would normally be an important part of a national flood control program to establish by statute a formula whereby the financing of projects from national funds will be administered on a uniform and economically justified basis.

8.3. The views heretofore expressed cover only a few of the principles and procedures involved in the planning of a national flood control program which I feel should be stressed. The Committee Report very thoroughly presents many other phases of the flood problem here as well as those concerning which the above comments have been made. After thorough review, I am in accord with all of the engineering principles set forth in the general chapters of Volume I of the Report and with the recommendations with which it concludes. My purpose in selecting certain phases for comment is to give additional stress to the principles and features of a national flood control program that seems to me to be especially important from the standpoint of sound engineering and economics, which are reiterated in brief as follows :

Sound hydrology—which will include an adequate program for the accumulation of data as well as full use of such data in planning and engineering.

Comprehensive planning—for river basins with national uniformity in design, standards and methodology.

Project planning—to embrace consideration of all reasonable alternative measures, including flood zoning, if feasible.

Economic justification—for all except emergent projects.

Sound project engineering—in the design, execution of construction, and operation of all projects.

Long-range programming—with assignment of priorities to individual projects.

Efficient financing—of project planning and construction on an orderly basis at a comparable level with other governmental functions.

It is my recommendation—that these principles be observed insofar as possible in any major flood control program to be undertaken.

H. E. HEDGER

APPENDIX A

A list of the more important Reports of Flood Committees and Experts in the various States of India

I. Andhra Pradesh

1. Report of the Godavari Flood Precautionary Committee, 1954.

II. Assam

1. Report of the Flood Enquiry Committee, Assam, 1929.
2. Report on Erosion at Dibrugarh by T. A. Curry dated 9.2.1937.
3. Note on River Problems in Assam by S. C. Majumdar.
4. Report of the Advisory Committee for the Reconnaissance and Survey of the Earthquake and Flood Affected Area in North-Eastern Assam, March 1951.
5. Report of the Iyengar Committee, 1952.
6. Report of G. R. Garg on the protection of Dibrugarh town and other flooded areas in Assam, 1952.

III. Bihar

1. Report of the Conference at Calcutta presided over by the Secretary to the Government of India in the P.W.D., 1896-97.
2. Report of the Monghyr (Begusaria) Advisory Committee, 1936.
3. Report of the Saran Advisory Committee, 1936.
4. Report of the Patna Conference, 1937.
5. Proceedings of the Committee formed to consider the material collected by the waterway engineers concerning flood conditions in North Bihar, 1937.
6. Report of C. C. Inglis, 1941.
7. Comprehensive Treatise on North Bihar flood problems giving a description of the river system, their behaviours and tendencies with suggestions for flood mitigation by P. C. Ghosh and K. K. Sahay, 1942.
8. Preliminary Report on the Kosi Dam Project by A. N. Khosla, Chairman, Central Water and Power Commission, 1946.

9. Report of the Advisory Committee on the Kosi Project, 1951.
10. Plan for Flood Control on the Kosi River by Kanwar Sain, Chairman, Central Water and Power Commission, 1953.
11. Report of the Advisory Committee on the Kosi Project (1953).
12. Report on field trip for flood control in North Bihar by B. E. Torpen and Clarence Rawhouser, December 1954.
13. Report on a Reconnaissance of Flood Control Problems in North Bihar by Luna B. Leopold and Thomas Maddock Jr., April 1955.
14. Report on Bank Protection on the Kosi River in North Bihar by H. E. Weller, July 1955.
15. Report on Flood Control Schemes at Dibrugarh and in North Bihar by Claude Inglis, May 1956.

IV. Jammu & Kashmir

1. Report on Hydraulic Problems in Kashmir by R. E. Purves, 1915.
2. Report on Flood Protective Works in Kashmir by Tulsi Das, 1928 (Appendix to Report on the Flood Problems in the Kashmir Valley by D. G. Harris).
3. Report on the Flood Problems in the Kashmir Valley by D. G. Harris, 1929.
4. Flood Control, Drainage and Reclamation in Kashmir Valley by H. L. Uppal, 1952.

V. Orissa

1. Report by R. H. Rhind, 1872.
2. Report of the Orissa Flood Committee, 1928.
3. Preliminary Note on the Flood Problem in Orissa by M. Visvesvaraya, 1937.
4. Preliminary Report of the Orissa Flood Advisory Committee, 1938.
5. Second Note on the Flood Problem in Orissa by M. Visvesvaraya, 1939.
6. First Interim Report of the Orissa Flood Advisory Committee, 1938-39.
7. Second Interim Report of the Orissa Flood Advisory Committee, January 1940.
8. Third Interim Report of the Orissa Flood Advisory Committee, February 1942.
9. Proceedings of Flood Conference held at Cuttack on the 15th and 16th March 1945.
10. Proceedings of the Provincial Flood Conference held at Cuttack on 21st November 1945.

11. Proceedings of the third Provincial Flood Conference held at Cuttack on the 1st June 1946.
12. Proceedings of the fourth Provincial Flood Conference held at Cuttack on the 7th January 1947.
13. Proceedings of the fifth Provincial Flood Conference held at Cuttack on the 30th June 1947.
14. Proceedings of the sixth Provincial Flood Conference held at Cuttack on the 16th December 1947.
15. Proceedings of the seventh Provincial Flood Conference held at Cuttack on the 15th June 1948.
16. Proceedings of the eighth Provincial Flood Conference.
17. Proceedings of the ninth Provincial Flood Conference held at Cuttack on the 8th July 1949.

VI. U. P.

1. Reports on Floods in the Eastern United Provinces by A. P. Watal, 1939.
2. Proceedings of the Inter-provincial Flood Conference held at Lucknow on January 5, 1939.
3. Proceedings of the Interim Inter-provincial Flood Committee, November 1939.
4. Report of the U. P. Flood Committee, 1948, published in 1954.

VII. West Bengal

1. Report by D. B. Horn, on the Damodar Floods, 1902.
2. Report by C. Addams Williams, on the Damodar River, 1913.
3. Note on the Damodar River, its Floods and the Problem of controlling them, by E. L. Glass, 1918.
4. Report of the Northern Bengal Flood Committee, 1922, published in 1925.
5. Report of the Damodar Flood Enquiry Committee, 1943-44.
6. Preliminary Memorandum on the Unified Developments of the Damodar River System by W. L. Voorudin, August 1945.
7. Report of the North Bengal Flood Control Advisory Committee, 1956.
8. Report of the West Bengal Flood Enquiry Committee, 1956.

A Note on Flood Embankments on Certain Rivers in China, Egypt, Italy, Japan and America

1. China

1.1. In **China**, it is said that Kwan, father of the Great Emperor Yu, attempted unsuccessfully to check the overflowing flood waters of the Yellow river by means of dykes in the third century B.C. Failing in these attempts, the floods were later abated by Emperor Yu by diversion through nine tidal channels. Dykes built in later times breached now and again and demanded constant watchfulness and considerable expense in their maintenance. The Yellow river carries an abnormal quantity of silt, being 50 per cent by weight of the river discharge during high floods. In consequence, the bed of the river between the embankments has been rising, necessitating raising of the embankments from time to time; till now the river-bed in places is over 30 feet higher than the adjoining country level. Because of the increasing height of the flood levels within the dykes, the recurring expenditure on their maintenance consuming a substantial portion of the Nation's income, and the enormous damage that ensued from every breach, many engineers have through generations thought of finding other methods of flood control to replace the unsafe and costly system of dykes.

1.2. The legend of Great Yu's success in disposing of flood waters of the Yellow river by dividing these into nine tidal outlets to the sea, where his father failed in controlling the floods with dykes, was a favourite argument in favour of dispersal of flood waters into several channels. Resort was also made to dredging at the outlet of the river by means of large iron rakes attached to tow boats to stir up the silt which might be carried away by the current, as silt deposition in the estuary was considered a menace. Storage dams also got suggested, but on account of the very heavy silt charge in these rivers, and the consequent short useful life of reservoirs there has been hesitancy in adopting this method of flood control.

1.3. Although there are thousands of miles of embankments on the various rivers in China and nearly half the population there lives in areas protected by dykes, yet the protection afforded by these is not considered adequate and

dependable. Necessity has been felt for supplementing these by other methods of flood control, and a great many works have been undertaken since the advent of present regime in China.

1.4. On the Huai river which drains an area of more than 77,200 square miles, further flood control measures by means of storage as well as channel improvement have been taken since 1950. Four reservoirs were completed by 1954 and another three were under construction. Improvement of 1850 miles of old and new channels was done and over 970 miles of dykes were reinforced and repaired. Besides these flood control measures on this river, the land drainage of the flood plain was also improved. These measures have now rendered the dykes along the middle reaches of the river, which were otherwise considered undependable, safe against the highest recorded flood.

1.5. On the Yunting river which is 362 miles long and has a drainage area of 18,700 square miles, large-scale soil conservation measures in the hilly and loess-deposit regions have been planned to control erosion, as also a number of detention reservoirs have been taken in hand. The largest of these storage reservoirs with a capacity of 1·84 million acre feet has already been completed, and this enabled the flood of 1953, the second highest on record on this river, to pass safely.

1.6. On the Yellow river not only 1110 miles of dykes were strengthened but to prevent these dykes from breaching in very big floods, two large retarding basins have been created between the Poichin dyke and the north main dyke and at the Tung Ping lake. In ordinary years the inhabitants in these flood retarding basins cultivate their lands but on occurrence of an unusual flood, the government assists the people to move into safety zones and compensates them for losses resulting from the flood.

1.7. The Yangtze river which is the longest in China being 3420 miles in length and which has a drainage area of 700,000 square miles with an annual rainfall ranging between 40 to 80 inches, has an extensive dyke system on it. In order to release the middle Yangtze from serious flood threats in spite of the strengthening of the dykes there, a huge flood diversion project has been completed there in 1952. This detention basin can store four million acre feet of flood water, thus lowering water level in the lower reaches. In the meantime, surveys and investigations for other measures have been in progress.

1.8. The above goes to show that in China, although great lengths of dykes have afforded protection to vast areas and teeming millions of people there, the dykes by themselves have not been regarded a very dependable and

adequate means of flood protection and necessity has been felt of supplementing the protection afforded by dykes and by other methods of flood control.

2. Egypt

2.1. The Nile in **Egypt** has a long history of flood control. This 6350-kilometer (3,937 miles) long river, the second longest in the world, drains about 3 million square kilometers (1·16 million square miles). Flowing through the plains of Egypt, it divides at the head of delta at Cairo into two branches, namely, the Rosetta and the Damietta, 240 kilometers (150 miles) long each.

2.2. The river is completely embanked from Aswan to the sea, a distance of 1200 kilometers (745 miles). During the high flood of 1878 the discharge at Khartum, where the Blue Nile and the White Nile meet, was 12,500 cubic meters per second (4,40,000 cusecs), at Aswan 12,100 cms. (4,27,000 cusecs) and at Cairo 10,300 cms. (3,64,000 cusecs). The maximum flood lift at Aswan was 9·80 meters (32 feet) and at Cairo 9·6 meters (31·5 feet). The river slope from Aswan to its mouth is quite flat, it being 1/13000 in summer and 1/12200 in high flood between Aswan and Cairo, which are 948 kilometers (589 miles) apart along the river during low supply and 900 kilometers (559 miles) during high supply. Along the two deltaic branches below Cairo it is 1/12500 during low flow.

2.3. Embankments on the Nile have afforded protection through centuries, though not without disasters whenever breaches have occurred. In 1863, a disastrous breach occurred on the Rosetta branch at Nadir and there was great loss of life. Serious breaches occurred on the Damietta branch in 1861, 1863, 1866, 1869, 1874 and 1878. The occurrence of breaches from time to time kept people in a state of anxiety and suspense during flood season, and on a high flood occurring, with a rumour of a breach, panicky conditions prevailed. A major breach in the embankment spelled national disaster. When a breach on the Damietta branch occurred in 1878, so great was the consternation of Ismail Pasha that in a fit of rage he telegraphed orders that the person in charge of the section of the dyke and the engineer should be thrown in the breach. The villagers steadfastly plunged into the breach, stood shoulder to shoulder across the escaping water and with the aid of torn-off doors and windows and whatever else they could lay hands on, closed the breach within half an hour. Thus a national disaster and the necessity of carrying out the senseless orders of the Pasha were averted, though this young official had completely turned grey in the meantime.

2.4. According to accounts of this river recorded by Dr. Hurst in 1944 there has been no breach of importance since 1878. But traditionally the

villagers would unite to take immediate action against any threat to the safety of the Nile embankments. Conditions have changed considerably since. The Aswan dam was built in 1902 and has been raised in height since. This dam along with the Gobel Aulia reservoir has been exercising a moderating effect on floods. Even so, during every flood season watchers are placed all along the embankments at short distances, and stocks of stone, timber and tools are kept in readiness for coping with emergencies.

2.5. With the new proposed dam on the Nile in Egypt the threat of floods in the valley would be further reduced.

2.6. According to Hurst about a hundred million tons of silt, which would occupy say 60 million cubic meters (50,000 acre feet), if deposited and consolidated, passed down the Nile in a high flood. Even with this quantity of silt the bed of the Nile seems to have recorded no appreciable rise.

2.7. Thus in Egypt, embankments have served to give protection against floods for centuries, although not without disasters off and on when major breaches occurred. The flood protection afforded by these embankments became increasingly assured with the moderating effect of reservoirs, and improved system of flood warning and flood forecasting.

3. Italy

3.1. The Po in **Italy** has an elaborate system of dykes. Many of the main dykes were built hundreds of years back but had been raised, repaired and strengthened from time to time. This river with a catchment area of 28,000 square miles and a length of 425 miles along its channel, drains nearly a third of Italy. A quarter of its length lies in a flat plain. The maximum discharge of the river is of the order of three lakh cusecs. Silt measurements taken in 1923-24 recorded over six million metric tons during the year at Pontelagoscuro which gave a rate of surface erosion of 1/3 inch per century in the catchment. The rainfall in the catchment varies from 20 inches to 120 inches per annum, the average rainfall over the catchment being 42 inches per annum. Even in the eighteenth century, apprehensions were expressed that the bed of the Po was rising as a result of the confining of the flood waters between embankments. In 1760, Firisi studied the problem particularly on the Reno, a tributary of the Po which was causing trouble. He came to the conclusion that instances of rising of beds were not on the Po nor were these caused by confinements of the waters between dykes and preventing the spread of sediment over the land, but the troublesome rising of river-bed occurred on the tributaries at places where they left the steep slopes of narrow valleys and entered the gentle slope in the plains.

3.2. Centuries back, the Po was a restless and meandering river which occasionally changed its bed. It divided into several branches between Piacenza and Parma. Now on account of the construction of dykes, the river is confined to a single channel which it has developed for itself.

3.3. The main dykes all along the Po have a top width of at least 16 feet, and carry very well-maintained highways on top. In the lower reaches, a reliance seems to have been placed on one main dyke on either side of the river. In the upper reaches, however, there is a network of subsidiary dykes in addition to the main dykes. A hundred miles from its mouth, the height of the dykes is about 25 feet. Where floods are the highest and the danger the greatest, there are two main dykes on either side at a considerable distance apart which provide a double line of defence.

3.4. The year 1926 witnessed a flood which surpassed all previous floods. The river rose to a height averaging about 1·3 feet higher than the top of the main dykes for many miles along the lower Po, but was prevented from overflowing them. 30,000 men are said to have toiled to build a continuous line of sandbag coffer dams from two to three feet high along more than 30 miles of length. So promptly and efficiently was this work done that breaches there were averted. In 1928, the main dykes were raised by a meter (3·3 feet).

3.5. Over centuries, flood heights have risen at the lower end of the Po. Like all rivers flowing through the alluvium into the sea, the Po has a delta which steadily advances into the Adriatic sea. During the past 2,000 years this delta has extended by more than 15 miles. This increase in the length of the river is an important factor in raising the bed and the low-water surface of the Po in its lower reaches. At a point which a thousand years ago marked the river mouth at sea level, the river surface at high flood now stands 10 to 15 feet higher than before, and this must affect the height of the river-bed and the height of water surface for a considerable distance upstream. This raising of the river-bed in the lower reaches caused by the extension of the delta and the consequent lengthening of the river-course cannot be laid against dykes. The only effect, which dykes when built right up to the mouth of such a river, bring about is the accelerated pace of extension of the delta into the sea, as the silt which ordinarily would have spread over the delta now finds its way into the sea.

4. Japan

4.1. In **Japan,** flood control by means of dykes has an early history and construction of embankments during 710-858 A,D. has been recorded. About

1600 A.D. major river training projects, which included construction of embankments, were commenced on the Tone river. Levee work was intensive during the Horeki era (1751-1763) in the Kiso-Ibi-Nagara basin. Here they developed a system of flood protection known as "waju", which consisted of enclosing of the area to be protected by embankments, the protected areas standing as islands in the midst of flooded area. This system got developed because of lack of comprehensive flood control planning. Levee systems were an important part of all river control programmes under the direction of Dutch engineers. As a result of these programmes and those planned during the current century all major rivers and most of the smaller streams are controlled by levees in their lower reaches. By March 1951*, about 4000 kilometers (2480 miles) of levees had been constructed or improved by the River Bureau or Prefectures and work on an equal length was under way. The larger levees have a crest width of 7·0-7·5 meters (23 to 24·5 feet) and smaller levees 5·0-5·5 meters (16·4 to 18 feet).

4.2. Although, as in other countries, dependence has largely been placed on levees for controlling floods in the past, other methods have increasingly been employed in recent times to supplement control by levees. The watershed management is receiving serious and sustained consideration and a good deal of headway has been made during the present century in this respect. The Japanese have used diversions and by-pass channels on a number of rivers for controlling floods in the lower reaches. The present diversion system on the Tone river is an outgrowth of the work started in 1613 and which centred in the plain area north of Tokyo. Other noteworthy examples are the Okuzu floodway on the Shinano river and the diversion channel at Yanadu on the Kitakami. A number of floodways have been planned. Some use is made of the pondage provided by natural lakes to control flood peaks by installing control weirs at the outlets of the lakes, such as at Lake Suwa at the head of the Tenrya river. Also besides a number of smaller detension basins, three large ones are functioning in the country, two on the Tone river system and one on the Kitakami. According to a report recorded in 1951 on "River Control and Utilization in Japan", there were no dams in the country, designed for flood control as such, although a number of dams built for irrigation and power afforded some incidental flood moderation. A number of multi-purpose dams have since been planned with flood control as one of the functions.

5. America

5.1. On the Mississippi river in the **U.S.A.** the earlier flood control works took the form of levee construction. The first of this system* was completed

*River Control and Utilization in Japan, 1951.

there in 1727. Later, other methods of flood control received consideration. In 1851, Mr. Charles Ellet suggested that the control of floods on the Mississippi should include the prevention of cutoffs ; the enlargement of natural river outlets ; the creation of artificial outlets and the construction of reservoirs. He also recommended the strengthening of the existing levee system. Although no exponent of levee system, Mr. Ellet also proposed the building of a line of setback levees parallel to the existing levees and with a freeboard of not less than six feet above the highest known floods. He apparently borrowed this idea from what the famous Chinese Engineer P'an Chi-Hsum had suggested for the Yellow river in the sixteenth century. The idea was that the existing dykes would serve as the first line of defence and in the event of their getting breached or overtopped in an extraordinary flood, the setback dykes would come into action and prevent the hinterland from getting flooded.

5.2. The report of Mr. Ellet was succeeded by the report of Messrs. Humphreys and Abott in 1861. In this report, they agreed that cutoff was a questionable method of river improvement and they strongly advocated the 'levees-only' method of flood control, disagreeing completely with Mr. Ellet on this point.

5.3. Further important reports on the flood protection on the Mississippi were those by Mr. Nelson after the 1897 floods and by Col. Townsend after the floods of 1913. Both advocated the 'levees-only' method of flood control. Col. Townsend who at that time was President of the Mississippi River Commission discussed six methods of flood control, namely, re-afforestation, reservoirs, cutoffs, outlets, floodways and levees. His report held that the effect of forests was negligible at very high stages of floods. The idea of reservoirs was not supported as he thought that an effective reservoir system in the rolling country which constituted a great part of the Mississippi valley could be obtained only by enormous expenditure quite disproportionate to the benefits to be derived from the reservoirs. Cutoffs were not recommended because it was believed that while they afforded some relief in the reaches immediately above the cutoffs they increased flood heights below. (This latter assertion is not considered correct.) Outlets were objected to on the ground that they would cause channel deterioration in the main channel below, and that they would require levee protection as well as the main river. Also it was felt, that the main river may leave its own channel for that of the outlet. Floodways were rejected stating that a channel capable of carrying the flood discharge of the river would necessarily have to be as large as the main river itself. Thus, the conclusion was in favour of the 'levees-only' theroy as that in Nelson's report.

5.4. The adequacy of protection particularly in the lower Mississippi basin again became a matter of controversy specially after the floods of 1927. On this river, already 1582 miles of earthen embankments had been built on two sides of the river in the jurisdiction of the Mississippi River Commission. It became apparent that the protection afforded by embankments alone could not be relied upon during very high floods. Additional measures were therefore thought out and carried out during the course of the next few years. A flood diversion of 5,50,000 cusecs has been provided at New Madrid on the west bank of the river. Flood waters enter this floodway through breaching sections in the levees at extremely high stages of the river. Lower down approximately 200 miles above the mouth of the river where the designed flood is of the order of three million cusecs, the flood control project for this river provides for a diversion of 1·2 million cusecs (six lakhs through the old river and another six lakhs through the Morganza floodway). Similarly 2,50,000 cusecs are diverted through the Bonnet Cairre spillway on the east bank of the river some 25 miles above its mouth. Besides the floodways, certain reservoirs have been built on the tributaries for moderating floods. Sixteen cutoffs across the major river banks have been made between the mouths of the Arkansas and the Red river, as a result of which the river length has been reduced by 170 miles. Vast sums have been spent in bank stabilisation, which in turn leads to the safety of the levees against erosion. Soil conservation also has not been neglected.

5.5. Thus, here also as in China, while embankments form the main defence against floods, other control measures have been adopted for ensuring more dependable protection.

APPENDIX C

A Note on the Rainfall Characteristics in the Ganga and the Brahmaputra Basins in relation to the Investigation of the Problem of Succession of Heavy Floods

by

India Meteorological Department

1. Meteorological Causes of Floods

1.1. Occurrence of heavy rainfall over a protion or the entire basin of the principal tributaries of the rivers Ganga and Brahmaputra for periods extending from 24 to 72 hours or more constitutes one of the principal meteorological causes of floods in these basins. On occasions, the rainfall may extend over several contiguous basins and the rainfall may occur simultaneously or in close successions, when chances of occurrence of floods are more pronounced.

1.2. The mountainous portions of the catchments are particularly liable to heavy rainfall, often with falls of great intensity ; at such times tributaries of the concerned basin begin to send down heavy discharges, as for example, down the Kosi, the Ghaghra, the Yamuna and the Teesta valleys.

1.3. Snow-melt may control the seasonal run-off in the Ganga and its main tributaries for certain parts of the year ; but studies seem to show that snow-melt does not constitute a major factor for causing floods. Even in the case of the Brahmaputra, though studied only roughly from this angle, it does not appear likely that snow-melt contributes appreciably towards occurrence of floods in the Brahmaputra.

1.4. It is well known that for the occurrence of floods, the precedent conditions in the catchment area and in the normal river channels play a very significant role. Therefore, the history of the precipitation over the areas under reference and the run-off in the normal river channels preceding the occurrence of the heavy fall are also of considerable importance and must be fully known.

1.5. For consideration of floods in the plains, *e g.*, the Gangetic plain, the conditions in the tributaries joining from the south constitute another important factor. As an illustration, take the case of heavy rainfall in the central part of India. The tributaries of the Ganga from the south begin to discharge heavily and shortly afterwards there is also heavy rainfall over the basins of some of the northern tributaries (rising in the Himalayan ranges). The discharge from these Himalayan tributaries following in the wake of the heavy discharge from the southern tributaries may cause floods over the Gangetic plains. One of the possible meteorological situations that may cause such a sequence of rainfall would be that a monsoon depression may pass over the Vindhya or Rajmahal hills, recurve and then break up over the Himalayan ranges.

2. The Meteorological Factors and Storm Characteristics in the Ganga and the Brahmaputra Basins

2.1. The meteorological situations that cause heavy rainfall over extensive areas are the Monsoon depressions and cyclonic storms which travel far inland. They cause heavy rainfall over areas along which they move. In some years the depressions may follow each other in quick succession along practically the same track, thus concentrating rainfall in a comparatively narrow belt of the country traversed by them. The rainfall may become particularly heavy when the depression breaks up over the mountains. It has also been observed that if the breaking up of the depression synchronizes with the passage of a western disturbance across the Himalayas, very heavy rainfall occurs over fairly extensive areas, some times even outside the mountain ranges where the depression breaks up. This combination of situations occurs more towards the end of the monsoon periods and is known to have caused several devastating floods in the past years.

2.2. The floods in the Brahmaputra in Assam are probably caused by heavy rainfall over the Himalayan ranges, some times quite in the interior of the Himalayas, under the influence of depressions breaking over the mountains combined with the passage of western disturbances, the intensity of the rainfall being augmented by the mountainous terrain.

2.3. Further, under very vigorous monsoon conditions exceptionally heavy rainfall is known to have occurred over the Himalayas in Assam and North Bengal and also in the other parts of the Himalayan foothills. Heavy rainfall, specially over the outer ranges of the Himalayas and on the adjoining plains due to strong monsoon may also cause floods in the Brahmaputra and some of the other rivers of North Bengal and Tripura-Assam border area.

2.4. A situation, known as "Break in the monsoon", causes heavy rainfall over the eastern Himalayas and the adjacent hills and plains and also in the Nepal Himalayas. During these breaks, the axis of the monsoon trough shifts well to the north, almost over the Himalayas, with consequent decrease of rainfall in the plains of northern India. Thus even in the absence of much rainfall over the plains, the rivers may be bringing in very heavy discharges as a result of the heavy rainfall over the mountainous portions of their catchment.

2.5. Another meteorological situation which causes heavy precipitation is associated with widespread and heavy thunder rain particularly along the axis of the monsoon trough and in Assam. Such outbreaks occur more during pre-monsoon or early monsoon periods. This widespread thunderstorm activity over the mountains and the adjoining plains causes heavy rainfall in the Brahmaputra basin leading to floods, though of much less severity.

3. A Brief Description of the Monsoon Characteristics in the Ganga and Brahmaputra Basins in 1954, 1955 and 1956

3.1. The monsoon of 1954 caused unprecedented floods in Assam, Sub-Himalayan West Bengal and North Bihar towards the end of July and again in the second fortnight of August.

3.2. Although the year's monsoon was characterised by the non-occurrence of usual monsoon depressions in the head Bay of Bengal during June and July, yet there was a quick succession of pressure waves that moved north-westwards across the Peninsula and helped maintaining active to vigorous monsoon in Gangetic West Bengal, Bihar and Assam.

3.3. Only two depressions formed in the Bay of Bengal during August, of which one was shortlived and the other was shallow. Consequently, the season's rainfall over Gangetic West Bengal and Chhota Nagpur remained deficient in spite of good rains in these areas during September.

3.4. An almost unique feature of this year was the movement of five active westerly low-pressure waves in rapid succession along the southern fringe of the Himalayas during the second half of July which led to a spell of heavy rain in the eastern Himalayas.

3.5. The monsoon in 1955 was characterised by its abnormal and prolonged activity towards the end of the season which was carried well into the month of October. The monsoon set in good time and kept up its activity during June. In July, however, there was a long break in the rains over the area except in and near the East Himalayas where heavy rain occurred. Very heavy

rains also occurred in East U.P. in the third week of July resulting in severe floods there. Earlier in the season, floods occurred in Assam, Sub-Himalayan West Bengal and Bihar which were less severe than previous year.

3.6. During the month of July no monsoon depression formed in the head Bay of Bengal but a number of westerly waves moved eastwards across the extreme north of the country and along the southern fringe of the Himalayas. Due to the passage of these westerly waves, heavy rain occurred in and near eastern Himalayas culminating in heavy floods from East U.P. to Assam. There was a deficiency of rainfall over Chhota Nagpur and adjoining central areas.

3.7. In 1956, the monsoon extended over a major part of the country for a period of about 5 months from the middle of May to middle of October instead of usual 4 months--June to September.

3.8. Due to a series of depressions and storms that formed in the Bay of Bengal and Arabian sea, monsoon continued to be active over the country throughout the period, resulting in season's total rainfall being above normal. The excessive rainfall gave rise to severe floods in Assam, West Bengal, Bihar, Uttar Pradesh and Punjab (India). Heavy floods in the Punjab and West U. P. occurred in the month of October.

3.9. The monsoon activity persisted almost throughout the country during September and continued till the second week of October, whereas normally it should have withdrawn by the end of September from Northwest India, West Uttar Pradesh, and Madhya Bharat. Its final withdrawal from Northwest India commenced as late as 13th October. The October rainfall in Punjab and Northwest Uttar Pradesh was particularly heavy resulting in record rise in the Yamuna and heavy floods in the Punjab and West U.P.

3.10. The chief weather characteristics associated with heavy rainfall during the 1954-56 monsoon seasons were :—

(i) Occurrence of monsoon depressions;

(ii) Periods of "break" in the monsoon with heavy rainfall in the Himalayan area, and

(iii) Movement of Westerly waves across the southern periphery of the Himalayas intensifying the convergence of the monsoon stream over the hills and causing spells of very heavy rain.

But these features occur in every monsoon season and are not peculiar to the last three monsoons; nor can it be said that the above characteristics can be considered as unusual or abnormal without parallel in previous years.

4. Assessment of Actual Rainfall in the Plains in the Monsoon Season (June to September) for the Years 1954, 1955 and 1956

4.1. Season's rainfall for the year 1954 was normal in Assam, West Bengal, Bihar and Uttar Pradesh. It was in slight defect in Chhota Nagpur, Vindhya Pradesh and East Rajasthan and in slight excess in Madhya Bharat.

4.2. Season's rainfall for the year 1955 was normal in Assam, West Bengal, Bihar, Vindhya Pradesh and West Uttar Pradesh. It was in slight defect in Chhota Nagpur and in slight excess in Madhya Bharat and East Rajasthan. Rainfall was in moderate excess in West Uttar Pradesh.

4.3. The season's rainfall for the year 1956 was in slight excess in West Bengal, Bihar and East Rajasthan; normal in Assam, Chhota Nagpur, Uttar Pradesh and Vindhya Pradesh and in slight defect in Madhya Bharat.

4.4. The following tables give the total rainfall during the season, in inches, its departure from normal and percentage departure from normal, for the various sub-divisions in the Brahmaputra and Ganga basins for the years 1954, 1955 and 1956.

Sub-Divisions	*Period (June to September)*		
	Actual	Departure from normal	Percentage Departure from normal
	1954		
1. Assam including Manipur and Tripura	63·78	+0·67	+ 1
2. West Bengal	48·51	−2·72	− 5
3. Bihar	39·03	−2·43	− 6
4. Chhota Nagpur	35·94	−8·49	−19
5. Uttar Pradesh, East	31·93	−2·93	− 8
6. Uttar Pradesh, West	31·26	−2·35	− 7
7. Vindhya Pradesh	35·66	−5·42	−13
8. Madhya Bharat	41·26	+8·05	+24
9. East Rajasthan	22·38	−3·10	−12

Sub-Divisions	Actual	*Period (June to September)* Departure from normal	Percentage Departure from normal
1955			
1. Assam including Manipur and Tripura	64·02	+ 1·49	+ 2
2. West Bengal	47·54	− 2·86	− 6
3. Bihar	43·48	+ 2·18	+ 5
4. Chhota Nagpur	32·94	−11·13	−25
5. Uttar Pradesh, East	49·14	+14·23	+41
6. Uttar Pradesh, West	36·13	+ 2·59	+ 8
7. Vindhya Pradesh	39·26	− 0·88	− 2
8. Madhya Bharat	38·00	+ 4·75	+14
9. East Rajasthan	30·37	+ 5·69	+23
1956			
1. Assam including Manipur and Tripura	61·78	−0·86	− 1
2. West Bengal	56·63	+5·58	+11
3. Bihar	46·46	+5·03	+12
4. Chhota Nagpur	47·26	+3·00	+ 7
5. Uttar Pradesh, East	36·54	+1·72	+ 5
6. Uttar Pradesh, West	35·10	+1·27	+ 4
7. Vindhya Pradesh	40·78	−0·94	− 2
8. Madhya Bharat	32·20	−4·30	−12
9. Rajasthan, East	28·15	+3·54	+14

5. Succession of Heavy Rain Storms during Recent Years ;— Are they unprecedented or are they due to a high rainfall cycle

5.1. While there have been some heavy rains in the Punjab, U.P. and Bengal in two or three successive years—1954 to 1956, it cannot be stated that these heavy rain spells are unprecedented. A recent study of the storms which affected the West U.P. and the Punjab areas in the last 50 years has shown that there had been a number of occasions in the past when rainfall of the magnitude which occurred in recent years in many of the areas had occurred in earlier years too. This year's September floods in the Yamuna near Mawana and Aligarh have been claimed to be of a very heavy magnitude and unprecedented. It may be seen from the table below that rainfall of the order that occurred in the districts concerned during this September's storm have occurred on a number of occasions in the past. The occasions listed in the table are not exhaustive. Similar storm rainfall studies, if carried out for the other areas, are expected to yield results leading to similar conclusions.

5.2. The study of the available data indicates that there is no cyclic trend in the monsoon as well as storm rainfalls in the Ganga and Brahmaputra basins. It may be emphasized, however, that for the study of trend, data for a very much longer period is necessary.

Very Heavy Rainfall Occasions in North-west Uttar Pradesh

(District averages of more than 2 inches in a day)

	September 1914	
District	**18th**	**19th**
Dehra Dun	4·15	4·04
Saharanpur	6·13	5·36
Muzaffarnagar	6·22	2·73
Meerut	5·68	2·03
Bijnor	7·10	6·31

		September 1924		
	28th	**29th**	**30th**	
Dehra Dun	4·78	6·47	3·56	(Mussoori 10·22" on 29th)
Saharanpur	3·91	5·27	6·29	(Hardwar 12" on 29th)
Muzaffarnagar	3·07	4·43	5·14	
Meerut	2·78	4·90	4·30	
Bijnor	6·12	7·30	4·15	

	September 1947		
District	**25th**	**26th**	
Dehra Dun	5·04	3·13	
Saharanpur	5·65	4·05	(Hardwar 8·00" on 25th)
Muzaffarnagar	2·90	...	(Kandhla 9·60" on 28th)
Meerut	2·70	...	
Bijnor	3·52	2·69	

	October	**1956**	
	9th	**10th**	
Dehra Dun	4·76	1·21	
Saharanpur	5·36	...	
Muzaffarnagar	5·85	...	
Meerut	5·01	2·49	(Mawana 11.12" on 9th)
Bijnor	5·37	1·89	

	September	**1880 ***	**Rainfall of individual station**		
	17th	**18th**		**17th**	**18th**
Dehra Dun	?	?			
Saharanpur	11·3	13·7	Roorkee/Hardwar	10·7/12·0	8·0/19·5
Muzaffarnagar	14·5	9·4	J. Jansath	16·0	14·6
			Muzaffarnagar	12·9	4·2
Meerut	16·0	12·1	Meerut	16·0	14·6
				?	15·5
Bijnor	9·9	25·9	Bijnor	12·4	12·4
			Nagina	8·6	32·4
			Dhampore	8·7	30·4
			Najibabad	10·1	28·5

	September 1923	
	22nd	**23rd**
Pilibhit	6·99	3·89
Shahjahanpur	4·70	6·25

* Averages based on scanty data of a few selected stations.

6. Conclusions

The following conclusions can, therefore, be drawn from what has been set out in the preceding sections :—

(1) The storm characteristics in the south-west monsoon seasons of the years 1954, 1955 and 1956, when heavy floods occurred in many of the rivers in North India, have not been unusual and abnormal and unparalleled in the previous years.

(2) Some of the very heavy rainfall amounts that were associated with the floods in recent years are not unprecedented, as rainfall amounts of similar magnitudes at individual districts or areas have occurred on a number of occasions off and on in the past.

(3) The study of available data of rainfall does not support the hypothesis of a periodicity in rainfall.

APPENDIX D

Note on the Principles and Procedure of the Statistical Analysis of Available Hydrological Data

by
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1. Introduction

1.1. The application of advanced statistical methods to any sample of data, particularly to the annual extreme events requires fulfilment of some basic assumptions. For example, that the data are random in nature depending on their magnitude and time of occurrence; that they are independent of each other and free from errors and inconsistencies; that the record of data is sufficiently long; that the sample of data is truly representative selection covering the whole period of time under consideration; and that the important hydrological conditions do not appreciably change during the period of record, and so on. As these are rarely the cases for the hydrological data, actual application of the statistical theory to such data suffers from grave limitations; but in the absence of any suitable alternative technique of analysis the methods of statistics, no doubt, do help us to a great extent in deriving some general conclusions regarding the various intriguing problems of the hydrological data. With this object in view, detailed statistical analysis has been carried out in respect of the annual maximum and minimum gauges of some of the rivers in the Ganga and the Brahmaputra basins.

1.2. The following paras deal with the principles and procedure of the statistical techniques employed in investigating a few problems connected with the procedure, recurrence and succession of the annual peak gauges and trend in the maximum and minimum gauges.

2. Problem of Precedence of the Maximum Gauges of the Recent Years

2.1. The analysis of this problem is based on the annual peak gauges on various rivers shown in graphs 1-5 of Volume III. Table D (i), which has

been prepared from these graphs, indicates the number of times the maximum flood gauge in recent years was exceeded in the past ; and also whether the highest floods in recent years are unprecedented or not.

2.2. In order to investigate whether a succession of high floods for 2 and 3 consecutive years as has been observed in the recent years has been unprecedented or not, 2 and 3 years' moving averages of the annual maximum gauges were computed and are plotted in graphs 9-13 of Vol. III.

2.3. Representing the maximum gauges for the years 1954, 1955, 1956, etc. by h_{54}, h_{55}, h_{56} ...... the two-year moving average is given by $(h_{54} + h_{55})/2$ and plotted against a point on the abscissa in between the years 1954 and 1955, while the three-year moving average is obtained by $(h_{54}+h_{55}+h_{56})/3$ and is plotted against the middle year 1955 and so on. The conclusions obtained from the graphs of these moving averages are further supplemented by the results in Table D (i).

3. Recurrence Interval of the Peak Flood Gauges

3.1. The recurrence interval is defined as the average interval of time (years) within which a magnitude of flood is equalled or exceeded. This is determined by the frequency analysis of the annual peak gauges. Among the various formulae put forward so far by different authors, the Gumbel's theoretical expression as applied by Ven Te Chow is considered to give fairly more precise estimates of the maximum values for assigned returned periods. Gumbel's equation can be represented by a simple linear relation :

$$Y_m = A \log_e \log_e \frac{T_m}{T_m - 1} \qquad \text{...........(1)}$$

where T_m is the recurrence interval or the return period and Y_m is the corresponding annual peak gauge.

3.2. The constants A and B are determined in several ways from the observed series of peak gauge values. Ven Te Chow suggested the method of least squares by considering $\log_e \log_e \dfrac{T_m}{T_m - 1}$ as an independent variable and equating T_m with $\dfrac{n+1}{m}$, where 'n' is the total number of years considered and 'm' is the rank of Y_m, when these peak gauge values (*i.e.*, Y_m values) of the 'n' years are arranged in descending order of magnitudes.

3.3. Accordingly, such equations giving the annual maximum gauges, Y_m, corresponding to the recurrence interval, T_m, are obtained as shown in column 8 of Table D (ii).

3.4. These equations are represented by straight lines in Figures 9 to 12 of this Volume where the ordinate represents the maximum gauge Y_m, and the abscissa gives the scale of $\log_e \log_e \frac{T_m}{T_m - 1}$ for different values of T_m. The observed plot of points ($T_m = \frac{n+1}{m}$, Y_m) shown with crosses indicates the degree of fitness of the observed series of data to the derived equations. It is, however, assumed that the errors which cause the scatter of plotted points exist only in the Y_m values inasmuch as the recurrence interval is computed on a theoretical basis and is considered as an independent variable.

3.5. With the help of these equations, the annual peak gauges for different return periods are calculated as given in Table D (ii) as also the return period or recurrence intervals corresponding to the highest maximum and the recent highest maximum gauges and shown in Table D (iii).

4. Recurrence Interval of Succession of High Floods

4.1. The determination of recurrence interval of a succession of high floods for 2 and 3 consecutive years as observed in the recent years is based on the theory of success runs, which though a classical topic, has found great applications in modern statistics. In the present problem this theory has been applied by considering the annual peak gauges as independent trials; the success of the trials being attained only when the gauge is equal to or greater than a preassigned magnitude of annual peak gauge such as danger level, highest flood level of the recent years, etc. Such consideration does not seem to raise any serious objection, but the limitation of the process is mainly due to the fact that the length of the series of data is too short and that the probability of success is estimated from a small number of observations as well as from the same sample of data. However, the analysis will no doubt give some useful idea of the chance of recurrence of the unprecedented succession of floods as in recent years.

4.2. According to the theory, the mean recurrence interval of a succession of annual flood gauge equal to or greater than, say (Y_c) for 'r' consecutive years is given by

$$M = \frac{1 - p^r}{qp^r} \qquad \text{.........(2)}$$

where $q=1-p$ and 'p' is the probability that annual maximum gauges are equal to or greater than Y_c. Since the value of 'p' is not known it may be estimated from the observed series of data by putting $p=k/n$, where 'n' is the

total number of years and 'k' is the number of times that the particular gauge Y_0 is equalled or exceeded during 'n' years.

4.3. The results obtained from equation (2) for a few sites which are of interest are given in Table D (iv).

5. Trend Analysis

5.1. Trend in general means a smooth broad motion of the system over a long term of years. As a matter of fact, no definite conclusion about rising or falling trend of hydro-meteorological series can be made from a short series of gauge data. The information about trend within the observed length of data will however be useful in searching out causes for unprecedented high floods recorded at a few sites during the recent years.

5.2. When the series has no very obvious smooth trend throughout the entire period, the trend component is usually represented locally by a polynomial in the time element, which is practically equivalent to the method of moving averages, by which different extreme variations in the annual peaks are smoothened out. In the absence of any regular periodicity in all the series, only 3 and 5 years' moving averages have been considered. The method of finding 3-year moving average has already been described. The 5-year moving averages are obtained exactly in the similar way by attributing the mean of 5 consecutive years' gauges to the central year of the group and are correspondingly plotted as shown in graphs 14 to 16 of Volume III.

5.3. The presence or absence of trend is further examined by a statistical test known as the non-parametric test for trend. This test procedure is carried out after ranking the maximum gauges in ascending order of magnitude. Then a number, kn wn as 'positive score' is determined by the number of times a particular year's gauge is exceeded in the succeeding years. If the sum of these positive scores corresponding to the different years is denoted by P then the quantity, $S=2P - \frac{n(n-1)}{2}$ is distributed normally with mean zero and variance $n(n-1)(2n+5)/18$, provided the number 'n' of total observations is large. To make a correction for continuity, unity is added to or subtracted from S if it is negative or positive respectively. To carry out the non-parametric test for trend it is therefore required to calculate the normal criteria, Z given by :

$$Z=\frac{S}{\sqrt{n(n-1)(2n+5)/18}} \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

If for a particular series of data Z is found from the tables for normal distribution to be significantly high, the existence of trend in the series would be inferred, otherwise not.

5.4. The values of Z obtained in this way both for annual maximum and minimum gauges are given in Table D (v) along with the general conclusions about trend as could be derived from these values of Z as well as from the moving average graphs (Graphs 9 to 16) of Volume III.

6. Concluding Remarks

In the preceding paras only the principles and procedures of the statistical methods employed in the study have been outlined. To avoid duplication, the discussion on the results of analysis has not been attempted, as that is already embodied in Chapter IX of this Volume.

TABLE D (i)

Statement giving the Number of Times the Peak Flood Gauge in recent years was exceeded in the past

S. No.	Name of site	1956	1955	1954	1953	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Paonta	1 in 41 years (36·0)	1 in 40 years (35 0)	8 in 39 years (29·2)	10 in 38 years (28·8)	Only gauge reading and not R.L.'s.
2.	Okhla	0 in 31 years (665·9)	0 in 30 years (664·7)	1 in 29 years (663 5)	5 in 28 years (662·8)	
3.	Elgin Bridge		13 in 18 years (347·84)	2 in 7 years (349 84)	3 in 16 years (348·83)	
4.	Inchcape Rly. Bridge			11 in 25 years (182·75)	10 in 24 years (182·75)	
5.	Raiwala		10 in 30 years (20·1)	8 in 29 years (20·2)	2 in 28 years (21·5)	
6.	Dighaghat		9 in 16 years (31·5)	12 in 15 years (29 8)	9 in 14 years (31·0)	
7.	Izat Rly. Bridge		11 in 31 years (275·0)	20 in 30 years (271·50)	17 in 29 years (272·75)	
8.	Dibrugarh	5 in 25 years (342·5)	0 in 24 years (314 1)	3 in 23 years (343 0)	12 in 22 years (341·0)	
9.	Tezpur	23 in 25 years (217·4)	4 in 24 years (219·8)	3 in 23 years (219·9)	15 in 22 years (218·2)	
10.	Gauhati	22 in 25 years (161·7)	8 in 24 years (164·3)	4 in 23 years (165 0)	11 in 22 years (163·3)	
11.	Dhubri	8 in 25 years (95 9)	0 in 24 years (97·7)	0 in 23 years (97·6)	18 in 22 years (94·8)	

Notes :—

(i) Figures in brackets are the maximum gauges in feet for the corresponding year.
(ii) Zero indicates that maximum gauge for the year has not been exceeded.

TABLE D (ii)

Maximum Gauges in feet for Various Return Periods together with their Statistical Relations

S. No.	Name of site	Return Period in Years					Equation giving estimates of annual maximum gauges Y (in feet) for different recurrence intervals T (in years)	Reference to Figure No.
		50	100	300	500	1000		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Yamuna							
1.	Paonta	37·9	39·8	43·0	44·3	46·6	$Y = -2{\cdot}81 \log_e \log_e \frac{T}{T-1} + 26{\cdot}90$	9
2.	Okhla	665·1	665·7	666·8	667·2	668·0	$Y = -0{\cdot}94 \log_e \log_e \frac{T}{T-1} + 661{\cdot}42$	9
	Ghaghra							
3.	Elgin Bridge	351·3	351·9	352·8	353·2	353·9	$Y = -1{\cdot}40 \log_e \log_e \frac{T}{T-1} + 347{\cdot}29$	10
4.	Inchcap Rly. Bridge	189·8	191·2	193·6	194·6	196·3	$Y = -2{\cdot}10 \log_e \log_e \frac{T}{T-1} + 181{\cdot}58$	10
	Ganga							
5.	Raiwala	25·8	27·4	30·0	31·1	32·9	$Y = -2{\cdot}30 \log_e \log_e \frac{T}{T-1} + 16{\cdot}87$	11
6.	Dighaghat	38·8	40·3	42·7	43·6	45·3	$Y = -2{\cdot}08 \log_e \log_e \frac{T}{T-1} + 30{\cdot}74$	11
7.	Izat Rly. Bridge	290·0	293·2	298·5	300·5	304·3	$Y = -4{\cdot}56 \log_e \log_e \frac{T}{T-1} + 272{\cdot}12$	11
	Brahmaputra							
8.	Dibrugarh	345·8	346·7	348·2	348·8	350·0	$Y = -1{\cdot}20 \log_e \log_e \frac{T}{T-1} + 340{\cdot}63$	12
9.	Tezpur	221·7	222·3	223·3	223·7	224·4	$Y = -0{\cdot}87 \log_e \log_e \frac{T}{T-1} + 218{\cdot}26$	12
10.	Gauhati	168·4	169·4	171·1	171·8	173·0	$Y = -1{\cdot}48 \log_e \log_e \frac{T}{T-1} + 162{\cdot}67$	12
11.	Dhubri	98·6	99·2	100·1	100·5	101·2	$Y = -0{\cdot}84 \log_e \log_e \frac{T}{T-1} + 95{\cdot}32$	12

TABLE D (iii)

Recurrence Interval for the Recorded Highest and the Recent Highest Maximum Gauges at Different Sites

S. No.	Name of Station	Year	Max. Gauge (Recorded) in ft.	Corresponding Recurrence Interval in years
1.	*Yamuna*			
	Paonta	1947	38·0	51
		1956	36·0	24
	Okhla	1956	665·9	101
		1955	664·7	33
2.	*Ghaghra*			
	Elgin Bridge	1937 1950	350·0	12
	Inchcape Rly. Bridge	1943	189·5	51
		1954 1953	182·7	2
3.	*Ganga*			
	Raiwala	1950	23·5	17
		1953	21·5	8
	Dighaghat	1948	38.9	51
		1955	31·5	2
	Izat Rly. Bridge	1948	289·9	51
		1955	275·0	2
4.	*Brahmaputra*			
	Dibrugarh	1955	344·1	19
		1954	343·0	8
	Tezpur	1942	220·3	11
		1954 1955	219·9	7
	Gauhati	1935	167·8	34
		1954	165·0	5
	Dhubri	1954 1955	97·7	17
		1956	95·9	2

TABLE D (iv)

Recurrence Interval of a Succession of Annual High Floods for 2 or 3 consecutive years

S. No.	Name of Site	2-year succession			3-year succession		
		Annual maximum gauge in feet (Y_0)	Probability that annual maximum is equal to or greater than Y_0	Recurrence interval in years	Annual maximum gauge in feet (Y_0)	Probability that annual maximum is equal to or greater than Y_0	Recurrence interval in years
1.	Paonta	35·6	0·071	216	—	—	—
2.	Okhla	664·7	0·062	277	663·5	0·125	555
3.	Dibrugarh	344·1	0·23	33	—	—	—

TABLE D (v)

Analysis of Trend in Annual Maximum and Minimum Gauges based on 3- and 5-year Moving Average Graphs and Non-parametric Test

Name of Site	Annual Maximum Gauge		Annual Minimum Gauge	
	Z	Remarks about trend	Z	Remarks about trend
(1)	(2)	(3)	(4)	(5)
Yamuna				
Paonta	1·76	No significant trend.	2·08	No significant trend.
Okhla	2·46	Rising trend suspected.	0·18	No trend.
Ghaghra				
Elgin Bridge	0·94	No trend.	—	
Inchcape Rly. Bridge	1·17	No trend.	—	
Ganga				
Raiwala	1·85	No significant trend.	3·63	Rising trend.
Dighaghat	—0·41	No trend.	—	
Izat Rly. Bridge	0·71	No trend.	—1·33	No trend.
Brahmaputra				
Dibrugarh	1·04	No trend.	0·16	No trend but substantial rise since 1948.
Tezpur	—0·24	No trend.	2·14	Rising trend suspected.
Gauhati	2·93	No trend.	2·93	Rising trend.
Dhubri	1·30	No trend.	4·03	Rising trend.

Notes :—

(i) 3- and 5-year moving averages are shown in graphs 9 to 16 of Volume III.

(ii) Values of criterion Z for the test are given in columns 2 and 4.

(iii) The significant values of Z at 5% and 1% level of significance are respectively 1·96 and 2·57, as given by Tables of normal distribution. If the observed values of columns 2 and 4 are greater than 5% value of Z but less than the 1% value of Z trend is only suspected. If they are greater than the 1% value of Z trend is present and if it is less than 5% value of Z trend is absent. The remarks in columns 3 and 5 are, however, made also in consideration of the moving average graphs (Figs. 9-15 of Vol. III).

APPENDIX E

Constitution and Functions of the Central Flood Control Board

GOVERNMENT OF INDIA

MINISTRY OF IRRIGATION AND POWER

No. DW 14 (19)/54 *New Delhi, the* 30th *September* 1954

RESOLUTION

Floods have been causing damage to life and property in various parts of the country at fairly regular intervals. The need for devising measures, immediate, short-term and long-term, to minimise this damage has been brought home by the extensive destruction caused by the recent floods which are unprecedented both in their intensity and duration. To ensure that flood control measures are formulated and carried out expeditiously, such of the States as are liable to frequent floods are being requested to constitute flood control boards. As it is desirable that a Central body should be appointed to consider the schemes prepared by the State Flood Control Boards and draw up a national flood control programme having regard to the available finance and technical personnel, the Government of India have decided to set up a Central Flood Control Board.

Constitution and Functions of Central Flood Control Board

2. Constitution as amended vide Irrigation and Power Ministry's gazette notifications :—

(i) No. DW 14 (7)/54 dated 20.9.1954.

(ii) No. DW V-14 (7)/54 (7) dated 22.8.1955.

(iii) No. DW V-516 (1)/57 dated 2.8.1957.

The Central Flood Control Board will consist of the following :—

Chairman

(i) Union Minister of Irrigation and Power

Members

(ii) Union Minister of Finance.

(iii) Union Minister of Railways.

(iv) Union Minister of Transport and Communications.

(v) Minister of Co-operation in the Ministry of Food and Agriculture.

(vi) Deputy Chairman, Planning Commission.

(vii) Deputy Minister of Education and Scientific Research.

(viii) Chairman, Advisory Committee on Irrigation and Power Projects set up by the Planning Commission.

(ix) One representative of each of the State Flood Control Boards, *i.e.*, Andhra Pradesh, Assam, Bihar, Bombay, Jammu and Kashmir, Madhya Pradesh, Mysore, Orissa, Punjab, Uttar Pradesh and West Bengal.

Secretary

(x) Secretary, Ministry of Irrigation and Power.

Additional Secretary

(xi) Chairman, Central Water and Power Commission.

Functions

3. The functions of the Central Flood Control Board will be :—

(a) to draw up a comprehensive plan for flood control and fix priorities ;

(b) to deal with matters relating to policy in connection with floods and flood control measures ;

(c) to examine and approve specific schemes proposed for the investigation and construction of flood control works in the States ;

(d) to arrange for necessary assistance in connection with investigation and planning and execution of flood control works ; and

(e) to devise measures to cope up with emergent situations.

4. The Board will frame its own rules of business.

ORDER

Ordered that this Resolution be communicated to all the State Governments, the several Ministries of the Government of India, the Comptroller and Auditor General of India, the Prime Minister's Secretariat, the Secretary to the President, the Planning Commission, the Rajya Sabha Secretariat and the Lok Sabha Secretariat.

Ordered also that the Resolution be published in Gazette of India and that the State Governments be requested to publish it in the State Gazettes for general information.

T. SIVASANKAR
Secretary to the Government of India

APPENDIX F

Constitution and Functions of the Ganga and the Brahmaputra River Commissions (Floods)

GOVERNMENT OF INDIA

MINISTRY OF IRRIGATION AND POWER

No. DW 14 (9)/54 *New Delhi, the* 30th *September* 1954

RESOLUTION

Floods in the States of U.P., Bihar and parts of West Bengal are caused by the Ganga and its tributaries, while the Brahmaputra and its tributaries are responsible for floods in the States of Assam and parts of West Bengal. The Central Flood Control Board constituted recently to deal with flood control problems in the country decided in their first meeting on the 15th September 1954, to set up two River Commissions, one for the Ganga basin and the other for the Brahmaputra basin, to assist the Board in all technical matters including preparation of integrated plans for flood control for the two basins and examination of specific schemes to be carried out in the States. The Government of India have, accordingly, set up the Ganga River Commission (Floods) and the Brahmaputra River Commission (Floods).

Constitution of the River Commissions

2. As amended vide Government of India, Ministry of Irrigation and Power Resolution No. DW V/14(9)/54-2 dated 31.10.1955.

(a) The Ganga River Commission (Floods) will consist of the following :—

Chairman

(i) Chairman, Central Water and Power Commission.

Members

(ii) Chief Engineer(s) in charge of Flood Control, U.P.

(iii) Chief Engineer(s) in charge of Flood Control, Bihar.

(iv) Chief Engineer(s) in charge of Flood Control, W. Bengal.

(v) Director, Central Water and Power Research Station, Poona.

(vi) Inspector-General of Forests or his representative.

(vii) Surveyor-General of India or his representative.

(viii) Director, Geological Survey of India, or his representative.

(ix) Director-General of Observatories, Meteorological Department, or his representative.

(x) Chairman, Railway Board, or his representative.

(xi) Chief Engineer, in charge of Kosi Project.

(xii) Chief Engineer, Flood Control, in charge of Planning, C.W. & P.C.

(xiii) Consulting Engineer (Road Development) and Joint Secretary, Ministry of Transport, or his representative.

Member-Secretary

(xiv) Chief Engineer (Flood Control) in charge of Field Investigations, Central Water and Power Commission.

(b) The Brahmaputra River Commission (Floods) will consist of the following :—

Chairman

(i) Chairman, Central Water and Power Commission.

Members

(ii) Chief Engineer(s) in charge of Flood Control, Assam.

(iii) Chief Engineer(s) in charge of Flood Control, W. Bengal.

(iv) Superintending Engineer, North-East Frontier Agency.

(v) Director, Central Water and Power Research Station, Poona.

(vi) Inspector-General of Forests or his representative.

(vii) Surveyor-General of India or his representative.

(viii) Director, Geological Survey of India, or his representative.

(ix) Director-General of Observatories, Meteorological Department, or his representative.

(x) Chairman, Railway Board, or his representative.

(xi) Chief Engineer (Flood Control) in charge of Planning, C.W. & P.C.

(xii) Consulting Engineer (Road Development) and Joint Secretary, Ministry of Transport, or his representative.

Member-Secretary

(xiii) Chief Engineer (Flood Control) in charge of Field Investigations, Central Water and Power Commission.

3. The two Commissions may co-opt specialists, Indian or foreign, as and when necessary.

Functions

4. The functions of the two Commissions will be to assist the Central Flood Control Board in all technical matters connected with flood control measures with particular reference to the following:—

(a) Preparation of a comprehensive programme for surveys and collection of data for formulation of flood control schemes.

(b) Preparation of integrated plans for the river basins after due consideration of the proposals of the State Government for flood control works.

(c) Review of the progress of work regarding the collection of data, preparation of schemes and their implementation.

(d) Advising the State Governments, whenever necessary, on technical problems pertaining to flood control.

(e) Recommendation of measures to cope with emergent situations.

5. The Commission will frame its own rules of business.

ORDER

Ordered that this Resolution be communicated to all the State Governments, the several Ministries of the Government of India, the Comptroller and Auditor General of India, the Prime Minister's Secretariat, the Secretary to the President, the Planning Commission, the Rajya Sabha Secretariat and the Lok Sabha Secretariat.

Ordered also that the Resolution be published in the Gazette of India and that the State Governments be requested to publish it in the State Gazettes for general information.

T. SIVASANKAR
Secretary to the Government of India

APPENDIX G

Constitution and Functions of the North West Rivers Commission (Floods)

GOVERNMENT OF INDIA

MINISTRY OF IRRIGATION AND POWER

No. DW. 14 (9)/54-(1) *New Delhi, the* 31st *January* 1955

RESOLUTION

Two River Commissions, namely, the Ganga River Commission (Floods) and the Brahmaputra River Commission (Floods) have already been set up to deal with flood control problems in the Ganga and the Brahmaputra basins vide this Ministry's Resolution No. DW. 14 (9)/54, dated the 30th Sepember 1954. The States of Jammu & Kashmir, PEPSU and Punjab are also affected by frequent floods and the State Governments have constituted State Flood Control Boards.

The Central Flood Control Board, in their second meeting held on the 14th December 1954, decided to set up another River Commission to assist the Board in all technical matters including preparation of integrated plans for flood control for the North-West region and examination of specific schemes to be carried out in the States. The Government of India have accordingly set up North West Rivers Commission (Floods).

Constitution of the River Commission

2. As amended vide Govt. of India, Ministry of I & P Resolution No. DW-V 14 (9)/54-(3) dated 3.10.1955.

The North West Rivers Commission (Floods) will consist of the following:—

Chairman

(i) Chairman, Central Water and Power Commission.

Members

(ii) Chief Engineer(s) in charge of Flood Control, Jammu & Kashmir.

(iii) Chief Engineer(s) in charge of Flood Control, Punjab.

(iv) Chief Engineer(s) in charge of Flood Control, PEPSU.

(v) Inspector-General of Forests or his representative.

(vi) Surveyor-General of India or his representative.

(vii) Director, Geological Survey of India, or his representative.

(viii) Director-General of Observatories, Meteorological Department, or his representative.

(ix) Chief Conservator of Forests, Himachal Pradesh.

(x) Chairman, Railway Board, or his representative.

(xi) Chief Engineer (Flood Control) in charge of Planning, C.W. & P.C.

(xii) Director, Hydraulic Research Station, Amritsar, Punjab.

(xiii) Consulting Engineer (Road Development) and Joint Secretary, Ministry of Transport, or his representative.

Member-Secretary

(xiv) Chief Engineer (Flood Control) in charge of Field Investigations, C.W. & P.C.

3. The Commission may co-opt specialists, Indian or foreign, as and when necessary.

Functions

4. The functions of the Commission will be to assist the Central Flood Control Board in all technical matters connected with flood control measures with particular reference to the following:—

(a) Preparation of a comprehensive programme for surveys and collection of data for formulation of flood control schemes.

(b) Preparation of integrated plan for the river basins, after due consideration of the proposals of the State Governments for flood control works.

(c) Review of the progress of work regarding the collection of data, preparation of schemes and their implementation.

(d) Advising the State Governments, whenever necessary, on technical problems pertaining to flood control.

(e) Recommendation of measures to cope with emergent situations.

5. The Commission will frame its own rules of business.

ORDER

Ordered that this Resolution be communicated to all the State Governments, the several Ministries of the Government of India, the Comptroller and Auditor General of India, the Prime Minister's Secretariat, the Secretary to the President, the Planning Commission, the Rajya Sabha Secretariat and the Lok Sabha Secretariat.

Ordered also that the Resolution be published in the Gazette of India and that the State Governments be requested to publish it in the State Gazettes for general information.

T. SIVASANKAR
Secretary to the Government of India

APPENDIX H

Constitution and Functions of the Central India Rivers Commission (Floods)

GOVERNMENT OF INDIA

MINISTRY OF IRRIGATION AND POWER

No. DW.V/14(42)/55 *New Delhi, the* 30th *November* 1955

RESOLUTION

Three River Commissions namely, the Ganga River Commission (Floods), the Brahmaputra River Commission (Floods) and the North West Rivers Commission (Floods) have already been set up to deal with flood control problems in the Ganga and the Brahmaputra basins and the North-West region. The States of Andhra, Madhya Pradesh, Orissa and Saurashtra are also affected by floods and the State Governments concerned have constituted State Flood Control Boards.

The Central Flood Control Board constituted on the 8th September 1954, to deal with flood control problems in the country decided in their fourth meeting on the 6th October 1955, to set up another River Commission to assist the Board in all technical matters including preparation of integrated plans for flood control for the basins of the rivers Godavari, Krishna and Mahanadi, and the rivers in Saurashtra and examination of specific schemes to be carried out in the States. The Government of India have, accordingly, set up the Central India Rivers Commission (Floods).

Constitution of the River Commission

2. The Central India Rivers Commission (Floods) will consist of the following :—

Chairman

(i) Chairman, Central Water and Power Commission.

Members

(ii) Chief Engineer in charge of Flood Control, Andhra.

(iii) Chief Engineer in charge of Flood Control, Orissa.

(iv) Chief Engineer in charge of Flood Control, Madhya Pradesh.

(v) Chief Engineer in charge of Flood Control, Saurashtra.

(vi) Chief Engineer, Irrigation Projects, Hyderabad-Deccan.

(vii) Director, Central Water and Power Research Station, Poona.

(viii) Inspector-General of Forests or his representative.

(ix) Surveyor-General of India or his representative.

(x) Director, Geological Survey of India, or his representative.

(xi) Director-General of Observatories, Meteorological Department, or his representative.

(xii) Chief Engineer, Southern Railway.

(xiii) Consulting Engineer (Road Development) and Joint Secretary, Ministry of Transport, or his representative.

(xiv) Chief Engineer (Flood Control) in charge of Planning, Central Water and Power Commission.

Member-Secretary

(xv) Chief Engineer (Flood Control) in charge of Field Investigations, Central Water and Power Commission.

3. The Commission may co-opt specialists, Indian or foreign, as and when necessary.

Functions

4. The functions of the Commission will be to assist the Central Flood Control Board in all technical matters connected with flood control measures with particular reference to the following :—

(a) Preparation of a comprehensive programme for surveys and collection of data for formulation of flood control schemes.

(b) Preparation of integrated plans for flood control works for the river basins after due consideration of the proposals of the State Governments.

(c) Review of the progress of work regarding the collection of data, preparation of schemes and their implementation.

(d) Advising the State Governments, whenever necessary, on technical problems pertaining to flood control.

(e) Recommendations of measures to cope with emergent situations.

5. The Commission will frame their own rules of business.

ORDER

Ordered that this Resolution be communicated to all the State Governments, the several Ministries of the Government of India, the Comptroller and Auditor General of India, the Prime Minister's Secretariat, the Secretary to the President, the Planning Commission, the Rajya Sabha Secretariat and the Lok Sabha Secretariat.

Ordered also that the Resolution be published in the Gazette of India and that the State Governments be requested to publish it in the State Gazettes for general information.

T. SIVASANKAR
Secretary to the Government of India

Typical Constitution and Functions of the State Flood Control Board and the Technical Advisory Committee

1. State Flood Control Board

1.1. The State Flood Control Board shall consist of the following members :—

Chairman

1. Chief Minister.

Members

2. Minister for Finance.
3. Minister in charge of Flood Control Works.
4. Development and Revenue Commissioner.

Secretary

5. Secretary in charge of Flood Control Works.

Additional Secretary

6. Chief Engineer in charge of Flood Control Works.

(In the case of Bihar, Administrator, Kosi Project and the Chief Engineer, Kosi Project, will be added as additional members.)

1.2. The Chief Minister may co-opt one or two official or non-official members as and when he considers it necessary.

1.3. The functions of the State Flood Control Board will be—

(a) to assess the flood problem in the State and to deal with questions of policy in connection with floods, flood relief and measures for flood control and protection;

(b) to arrange for collection of the requisite data in accordance with an approved programme;

(c) to evolve and organise a flood warning system in the State;

(d) to plan the necessary remedial measures and to determine priorities;

(e) to arrange for the implementation of approved schemes according to an authorised schedule;

(f) to arrange for the efficient maintenance of flood control works;

(g) to devise measures to cope with emergent situations.

1.4. The State Flood Control Board will meet as and when necessary but *not less than once in 3 months.*

1.5. The Chairman will represent the State Flood Control Board on the Central Flood Control Board or nominate one of the members to represent the State Flood Control Board.

2. Technical Advisory Committee

2.1. In the discharge of the above functions the State Flood Control Board will be assisted by a Technical Advisory Committee consisting of the following members :—

Chairman

(i) Chief Engineer, Flood Control.

Members

(ii) A representative of the C.W. & P.C.

(iii) Director of State Research Station.

(iv) Chief Engineer, Roads.

(v) A representative of local railway engineering department.

(vi) Distinguished Engineer or other non-official in the State who may be familiar with the problem to be nominated by the Chief Minister.

Secretary

(vii) Superintending Engineer in charge of Flood Investigations.

2.2. The Technical Committee shall perform the following functions :–

(a) Arrangement for collection of the requisite data in accordance with the approved programme.

(b) Organisation of flood warning system for the State.

(c) Working out necessary remedial measures and relative priorities.

(d) Implementation of approved schemes in accordance with authorised schedules of constructions.

(e) Arrangements for efficient maintenance of flood control works.

(f) Technical advice on any other connected matters referred to by the State Flood Control Board.

2.3. The Technical Advisory Committee shall meet at least once in two months. A full account of the details of discussions at the meetings will be maintained. The Committee will frame its own rules of business.

APPENDIX K

A Statement of the Functions of the various Flood Control Organisations in India

S. No. (1)	Central Flood Control Board (2)	River Commissions (3)	State Flood Control Boards (4)	Technical Advisory Committees (5)
1.	To draw up a comprehensive plan for flood control and fix priorities.	Preparation of integrated plans for river basins after due consideration of the proposals of the State Governments.	To plan the necessary remedial measures and to determine priorities.	Working out necessary remedial measures and relative priorities.
2.	To deal with matters relating to policy in connection with flood control measures.	Preparation of comprehensive programme for surveys and collections of data for formulation of flood control schemes.	To assess the flood problem in State, and to deal with questions of policy in connection with floods, flood relief and measures for flood control and protection.	Technical advice on any other connected matters referred to by the State Flood Control Board.
3.	To examine and approve specific schemes proposed for the investigation and construction of flood control works in the States.	Review of the progress of work regarding the collection of data, preparation of schemes and their implementation.	To arrange for the collection of the requisite data in accordance with an approved programme.	Arrangement for collection of requisite data in accordance with an approved programme.
4.	To arrange for necessary assistance in connection with investigations, planning and execution of flood control works.	Advising the State Governments whenever necessary, on technical problems pertaining to flood control.	To arrange for the implementation of approved schemes according to an authorised schedule.	Implementation of the approved schemes in accordance with authorised schedules of constructions.
5.	To devise measures to cope with emergent situations.	Recommendation of measures to cope with emergent situations.	To devise measures to cope with emergent situations.	
6.			To evolve and organise a flood warning system in the State.	Organisation of flood warning system for the State.
7.			To arrange for the efficient maintenance of flood control works.	Arrangement for efficient maintenance of flood control works.

TABLE 1

Abstract of Total Flood Damage in various States during 1950-56 in Lakh Rupees

S. No.	Name of State	1950	1951	1952	1953	1954	1955	1956	Total damage from 1950 to 1956	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1.	Andhra	N.A.	298	132	N.A.	N.A.	144	33	607	(1) The figures of damage shown in all tables have been taken from the data supplied by the States from time to time.
2.	Assam	360	451	401	85	1,621	431	370	3,719	
3.	Bihar	257	6	82	3,650	2,150	2,162	573	8,880	
4.	Bombay	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	177	177	
5.	Delhi	N.A.	N.A.	N.A.	N.A.	N.A.	32	6	38	
6.	Himachal Pradesh	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	2	2	(2) Where damage figures are not available, these have been assumed to be small, and the tables worked out without them.
7.	Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	57	N.A.	5	62	
8.	Kerala	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3	3	
9.	Madhya Pradesh	N.A.	N.A.	N.A.	12	N.A.	8	1	21	
10.	Madras	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1	1	
11.	Manipur	N.A.	N.A.	5	N.A.	N.A.	N.A.	2	7	(3) N. A. signifies 'information not available'.
12.	Orissa	N.A.	N.A.	N.A.	N.A.	N.A.	1,039	224	1,263	
13.	Pondicherry	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1	1	
14.	Punjab	N.A.	1	N.A.	N.A.	95	4,696	3	4,795	(4) In all the tables, figures have been rounded up to the nearest whole numbers.
15.	Rajasthan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	15	15	
16.	Tripura	N.A.	N.A.	N.A.	N.A.	N.A.	5	13	18	
17.	Uttar Pradesh	1,450	245	N.A.	1,293	851	3,930	2,858	10,627	
18.	West Bengal	24	14	24	16	1,050	150	775	2,053	
	TOTAL	2,091	1,015	644	5,056	5,824	12,597	5,062	32,289	

TABLE 2

Flood Damage in various States during 1950-56 in Order of Magnitude

S. No.	Name of State	Total damage in 1950-56 in lakh rupees	Per cent of total damage in India	Annual average damage in lakh rupees	Total crop damage in 1950-56 in lakh rupees	Crop damage as per cent of total damage in each State	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Uttar Pradesh	10,627	33	1,518	7,950	75	Punjab includes Pepsu, and Bombay includes Saurashtra.
2.	Bihar	8,880	27	1,269	7,084	80	
3.	Punjab	4,795	15	685	2,183	46	
4.	Assam	3,719	12	531	2,420	65	
5.	West Bengal	2,053	6	293	1,570	77	
6.	Orissa	1,263	4	180	1,003	79	
7.	Andhra	607	2	87	424	70	
8.	Bombay	177		25	52	29	
9.	Jammu & Kashmir	62		9	27	44	
10.	Delhi	38		5	19	50	
11.	Madhya Pradesh	21		3	10	50	
12.	Tripura	18		3	18	100	
13.	Rajasthan	15	1	2	Nil	Nil	
14.	Manipur	7		1	5	70	
15.	Kerala	3			N.A.	N.A.	
16.	Himachal Pradesh	2			1	50	
17.	Pondicherry	1		1	1	100	
18.	Madras	1			1	100	
	TOTAL	32,289	100	4,612	22,768		

TABLE 3

Damage to Crops and Property in India during the Years 1950-56

Years	Total damage in lakh rupees	Damage to crops in lakh rupees	Damage to crops as percentage of total damage	Damage to houses in lakh rupees	Damage to houses as percentage of total damage	Damage to public utilities in lakh rupees	Damage to public utilities as percentage of total damage
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950	2,091	1,560	75	379	18	152	7
1951	1,015	695	69	253	25	67	7
1952	644	237	37	288	45	119	18
1953	5,056	4,024	80	742	15	290	6
1954	5,824	4,207	72	1,002	17	615	10
1955	12,597	8,009	64	3,837	30	751	5
1956	5,062	4,036	80	870	17	156	3
TOTAL	32,289	22,768	70	7,371	23	2,150	7

TABLE 4

Total Damage per Capita and Crop Damage per acre of the Net Area sown in the various States

S. No.	Name of State	Total population of the State according to 1951 census in lakhs	Average annual damage during 1950-56 in lakh rupees	Average annual damage per capita in rupees	Net area sown in thousand acres 1953-54	Average anuual crop during 1950-56 in lakh rupees	Average annual crop damage per acre of the area sown in rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	Andhra Pradesh	*	87	N.A.	15,611	71	*/*	*Not worked out on
2.	Assam	90·44	531	6	5,499	346	7	account of reorganisation of the State.
3.	Bihar	402·26	1,269	3	21,500	1,012	5	
4.	B mbay	400·93	25	*/*	44,685	7	*/*	
5.	Delhi	17·44	5	*/*	224	3	1	
6.	Madhya Pradesh	212·48	3	*/*	29,434	1	*/*	Bombay includes
7.	Manipur	5·78	1	*/*	203	1	*/*	Saurashtra.
8.	Orissa	146·46	180	1	13,996	143	1	
9.	Punjab	161·35	685	4	15,868	312	2	Punjab includes
10.	Tripura	6·39	3	*/*	429	3	1	PEPSU.
11.	Uttar Pradesh	632·16	1,518	2	40,609	1,136	3	*/* Less than one
12.	West Bengal	248·10	293	1	11,730	224	2	rupee.

Note:— Figures under cols. 3 and 6 have been taken from "Statistical Abstract, India 1953-1954", New Series No. 5. Under column 6, the area sown more than once has been counted only once.

TABLE 5

Flood Damage in various States during 1950

S. No.	Name of State	Area affected in thousand acres	Population affected	Damage to crops: Area in thousand acres	Damage to crops: Value in lakh rupees	Damage to houses: Nos.	Damage to houses: Value in lakh rupees	Cattle Lost (Nos.)	Human lives lost (Nos.)	Damage to public utilities in lakh rupees	Total damage in lakh rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	Andhra	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N. A. signifies "Information not available".
2.	Assam	576	N.A.	N.A.	250	N.A.	100	5,000	564	10	360	
3.	Bihar	338	N.A.	N.A.	100	N.A.	150	150	N.A.	7	257	
4.	Delhi	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
5.	Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
6.	Madhya Pradesh	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
7.	Manipur	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
8.	Orissa	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
9.	Punjab	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
10.	Tripura	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
11.	Uttar Pradesh	2,600	N.A.	N.A.	1,200	N.A.	125	2,200	128	125	1450	
12.	West Bengal	64	N.A.	N.A.	10	N.A.	4	3,000	80	10	24	
	TOTAL	3,578	...	...	1,560	...	379	10,350	772	152	2,091	

TABLE 6

Flood Damage in various States during 1951

S. No.	Name of State	Area affected in thousand acres	Population affected (Number of families)	Damage to crops: In thousand tons	Damage to crops: Value in lakh rupees	Damage to houses: Nos.	Damage to houses: Value in lakh rupees	Cattle lost (Nos.)	Human lives lost (Nos.)	Damage to public utilities in lakh rupees	Total damage in lakh rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	Andhra	116	5,252	54 (Rice)	269	1,313	3	N.A.	N.A.	26*	298	*Represents only value of 52 bridges damaged.
2.	Assam	836	50,000	N.A.	220	N.A.	220	7,000	4	11	451	
3.	Bihar	7	N.A.	N.A.	2	N.A.	4	50	N.A.	Nil	6	
4.	Delhi	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N. A. signifies "Information not available".
5.	Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
6.	Madhya Pradesh	819	4,560	N.A.	Nil	N.A.	N.A.	13	N.A.	N.A.	Nil	
7.	Manipur	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
8.	Orissa	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
9.	Punjab	608	N.A.	N.A.	1**	N.A.	N.A.	N.A.	N.A.	N.A.	1	** Assumed.
10.	Tripura	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
11.	Uttar Pradesh	252	N.A.	N.A.	200	N.A.	25	500	N.A.	20	245	
12.	West Bengal	Nil	N.A.	N.A.	3	N.A.	1**	750	N.A.	10	14	
	TOTAL	2,638	59,812	54	695	1313	253	8,313	4	67	1,015	

TABLE 7

Flood Damage in various States during 1952

S. No.	Name of State	Area affected in thousand acres	Population affected (Number of families)	Damage to crops		Damage to houses		Cattle lost (Nos.)	Human lives lost (Nos.)	Damage to public utilities in lakh rupees	Total damage in lakh rupees	Remarks
				Area in thousand acres	Value in lakh rupees	Nos.	Value in lakh rupees					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	Andhra	146	18,580	N.A.	2	21,470	44	1,42,513	N.A.	86*	132	*Value of 856
2.	Assam	6,400	1,22,000	N.A.	190	N.A.	190	5,441	7	21	401	Irrigation
3.	Bihar	99	N.A.	N.A.	30	N.A.	50	50	N.A.	2	82	Schemes and
4.	Delhi	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Wells.
5.	Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N. A. Signifies
6.	Madhya Pradesh	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	"Information
7.	Manipur	3	2,200	3	5	10	Nil	10	Nil	Nil	5	not available".
8.	Orissa	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
9.	Punjab	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
10.	Tripura	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
11.	Uttar Pradesh	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
12.	West Bengal	84	N.A.	N.A.	10	N.A.	4	3,000**	8	10**	24	** Assumed.
	TOTAL	6,732	1,42,780	3	237	21,480	288	1,51,014	15	119	644	

TABLE 8

Flood Damage in various States during 1953

S. No.	Name of State	Area affected in thousand acres	Population affected (Nos. of families)	Damage to crops: Area in thousand acres	Damage to crops: Value in lakh rupees	Damage to houses: Nos.	Damage to houses: Value in lakh rupees	Cattle lost (Nos.)	Human lives lost (Nos.)	Damage to public utilities in lakh rupees	Total damage in lakh rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	Andhra	176	6,64,545	N.A.	N.A.	N.A.	N.A.	40,509	N.A.	N.A.	N.A.	N. A. signifies
2.	Assam	207	77,000	N.A.	30	N.A.	30	837	4	25	85	"Information not
3.	Bihar	7,300	N.A.	N.A.	2,900	N.A.	600	750	N.A.	150	3,650	available".
4.	Delhi	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
5.	Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
6.	Madhya Pradesh	9,634	51,453	N.A.	7	N.A.	N.A.	2,872	2	5*	12	* Value of 2
7.	Manipur	5	4,000	1	N.A.	Nil	Nil	1,436	Nil	Nil	N.A.	major bridges
8.	Orissa	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	washed away.
9.	Punjab	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
10.	Tripura	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
11.	Uttar Pradesh	2,251	35,92,434	N.A.	1,082	80,443	111	341	23	100	1,293	
12.	West Bengal	6	N.A.	N.A.	5	N.A.	1	1,000**	N.A.	10 **	16	** Assumed.
	TOTAL	19,579	43,89,432	1	4,024	80,443	742	47,745	29	290	5,056	

TABLE 9

Flood Damage in various States during 1954

S. No.	Name of State	Area affected in thousand acres	Population affected in lakhs	Damage to crops: Area in thousand acres	Damage to crops: Value in lakh rupees	Damage to houses: Nos.	Damage to houses: Value in lakh rupees	Cattle lost (Nos.)	Human lives lost (Nos.)	Damage to public utilities in lakh rupees	Total damage in lakh rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	Andhra	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N. A. signifies "Information not available".
2.	Assam	7,776	13	814	1,173	N.A.	333	[illegible],845	17	115	1,621	
3.	Bihar	6,400	2	N.A.	1,500	N.A.	500	608	42	150	2,150	
4.	Delhi	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
5.	Jammu & Kashmir	112	1	N.A.	27*	1,000	30*	1,000	15	N.A.	57	
6.	Madhya Pradesh	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	* Assumed.
7.	Manipur	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
8.	Orissa	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
9.	Punjab	3	4	N.A.	75	800	20*	N.A.	N.A.	N.A.	N.A.	
10.	Tripura	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	95	
11.	Uttar Pradesh	3,335	34	1,838	682	19,550	19	1,553	27	N.A.	N.A.	
12.	West Bengal	1,050	N.A.	N.A.	750	N.A.	100	1,500	142	150*	851	
										200	1,050	
	TOTAL	18,676	54	2,652	4,207	21,350	1,002	13,506	243	615	5,824	

TABLE 10

Flood Damage in various States during 1955

S. No.	Name of State	Area affected in thousand acres	Population affected in lakhs	Damage to crops		Damage to houses		Cattle lost (Nos.)	Human lives lost (Nos.)	Damage to public utilities in lakh rupees	Total damage in lakh rupees	Remarks
				Area in thousand acres	Value in lakh rupees	Nos.	Value in lakh rupees					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	Andhra	507	N.A.	485	126	3,569	7	1,358	18	11	144	N. A. signifies
2.	Assam	3,462	8	N.A.	247	N.A.	53	3,558	Nil	131	431	"Information
3.	Bihar	4,378	71	2,491	2,030	1,11,856	112	57	44	20	2,162	not available".
4.	Delhi	80	N.A.	N.A.	15	N.A.	14	24	7	3	32	
5.	Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
6.	Madhya Pradesh	83	N.A.	N.A.	3	1,196	4	266	5	1	8	
7.	Manipur	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
8.	Orissa	1,639	20	1,009	788	1,29,591	176	4,641	79	75	1,039	
9.	Punjab	6,350	69	1,226	2,107	1,93,000	2,239	67,782	595	350	4,696	
10.	Tripura	4	N.A.	N.A.	5	N.A.	N.A.	Nil	Nil	N.A.	5	
11.	Uttar Pradesh	10,100	140	6,346	2,638	7,68,264	1,232	5,694	231	60*	3,930	* Assumed.
12.	West Bengal	855	N.A.	N.A.	50	600	N.A.	20	2	100	150	
	TOTAL	27,458	308	11,557	8,009	19,08,076	3,837	83,400	981	751	12,597	

TABLE 11

Flood Damage in various States during 1956

S. No.	Name of State	Area affected in thousand acres	Population affected in lakhs	Damage to crops: Area in thousand acres	Damage to crops: Value in lakh rupees	Damage to houses: Nos.	Damage to houses: Value in lakh rupees	Cattle lost (Nos.)	Human lives lost (Nos.)	Damage to public utilities in lakh rupees	Total damage in lakh rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	Andhra	3,434	2	125	27	3,460	2	4	126	4	33	N. A. signifies "Information not available".
2.	Assam	1,480	6	209	310	8,737	13	1,561	19	47	370	
3.	Bihar	2,645	31	986	522	79,879	51	138	32	N.A.	573	
4.	Bombay	N.A.	16	513	52	44,857	111	6,788	68	14	177	
5.	Delhi	19	1	14	4	1,700	2	N.A.	N.A.	N.A.	6	
6.	Himachal Pradesh	N.A.	N.A.	N.A.	1	N.A.	N.A.	N.A.	13	1	2	
7.	Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	5	5	
8.	Kerala	56	2	3	N.A.	2,727	3*	Nil	5	N.A.	3	
9.	Madhya Pradesh	92	N.A.	N.A.	N.A.	310	1*	43	Nil	N.A.	1	
10.	Madras	8	N.A.	3	1	581	N.A.	3	15	N.A.	1	* Assessed.
11.	Manipur	11	N.A.	1	N.A.	292	2	1	Nil	Nil	2	
12.	Orissa	806	9	222	215	3,187	9	1,192	Nil	N.A.	224	
13.	Pondicherry	1	N.A.	1	1	164	N.A.	Nil	Nil	Nil	1	
14.	Punjab	333	1	1	N.A.	751	1	N.A.	N.A.	2	3	
15.	Rajasthan	N.A.	N.A.	N.A.	N.A.	5,400	15@	1,405	15	N.A.	15	@ Assumed.
16.	Tripura	80	1	N.A.	13	1,427	N.A.	86	12	N.A.	13	
17.	Uttar Pradesh	6,183	86	N.A.	2,148	4,01,889	660	2,595	155	50@	2,858	
18.	West Bengal	6,541	9	999	742	1,99,556	N.A.	2,904	55	33	775	
	TOTAL	21,689	164	3,076	4,036	7,54,917	870	16,720	515	156	5,062	

TABLE 12

Flood Damage and Relief Expenditure in different River Systems during 1950-56 (in Lakh Rupees)

S. No.	Name of river system and State	Damage							Total damage	Relief				Total relief	Remarks
		1950	1951	1952	1953	1954	1955	1956		1950-53	1954	1955	1956		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1.	**Ganga River System**														
	Delhi	N.A.	N.A.	N.A.	N.A.	N.A.	32	6	38	N.A.	N.A.	3	5	8	* 63% of the total damage in India.
	Uttar Pradesh	1,450	245	N.A.	1,293	851	3,930	2,858	10,627	105	30	284	190	609	
	Bihar	257	6	82	3,650	2,150	2,162	573	8,880	1,668	415	337	252	2,672	
	West Bengal	Nil	Nil	Nil	Nil	Nil	Nil	775	775	Nil	Nil	Nil	327	327	
	TOTAL	1,707	251	82	4,943	3,001	6,124	4,212	20,320*	1,773	445	624	774	3,616	
2.	**Brahmaputra River System**														
	Assam	360	451	401	85	1,621	431	370	3,719	67	84	134	21	306	**16% of the total damage in India.
	West Bengal	24	14	24	16	1,050	150	Nil	1,278	5	46	178	Nil	229	
	TOTAL	384	465	425	101	2,671	581	370	4,997**	72	130	312	21	535	

North Western River System														
Jammu & Kashmir	N.A.	N.A.	N.A.	N.A.	57	N.A.	5	62	N.A.	N.A.	N.A.	N.A.	N.A.	† 15% of the
Punjab	N.A.	1	N.A.	N.A.	95	4,696	3	4,795	N.A.	N.A.	779	31	810	total damage in
Himachal Pradesh	N.A.	N.A.	N.A.	N.A.	N.A.	2	2	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	India.
TOTAL	N.A.	1	N.A.	N.A.	152	4,698	10	4,859†	N.A.	N.A.	779	31	810	
Other River Systems														
Andhra	N.A.	298	132	N.A.	N.A.	144	33	607	N.A.	N.A.	N.A.	9	9	††6% of the
Bombay	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	177	177	N.A.	N.A.	N.A.	56	56	total damage in
Kerala	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3	3	N.A.	N.A.	N.A.	N.A.	N.A.	India.
Madhya Pradesh	N.A.	N.A.	N.A.	12	N.A.	8	1	21	N.A.	N.A.	N.A.	1	1	
Madras	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1	1	N.A.	N.A.	N.A.	N.A.	N.A.	
Manipur	N.A.	N.A.	5	N.A.	N.A.	N.A.	2	7	N.A.	N.A.	N.A.	N.A.	N.A.	
Orissa	N.A.	N.A.	N.A.	N.A.	N.A.	1,039	224	1,263	N.A.	N.A.	306	266	572	
Pondicherry	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1	1	N.A.	N.A.	N.A.	N.A.	N.A.	
Rajasthan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	15	15	N.A.	N.A.	N.A.	N.A.	N.A.	
Tripura	N.A.	N.A.	N.A.	N.A.	N.A.	5	13	18	N.A.	N.A.	N.A.	10	10	
TOTAL	N.A.	298	137	12	N.A.	1,196	470	2,113††	N.A.	N.A.	306	342	648	
GRAND TOTAL	2,091	1,015	644	5,056	5,824	12,597	5,062	32,289@	1,845	575	2,021	1,168	5,609	@ 100%

TABLE 13

Damage in the Ganga Basin during 1950-56

S. No.	Year	Damage to crops: In lakh rupees	Damage to crops: Per cent of total damage	Damage to houses: In lakh rupees	Damage to houses: Per cent of total damage	Damage to public utilities: In lakh rupees	Damage to public utilities: Per cent of total damage	Total damage in lakh rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	1950	1,300	76	275	16	132	8	1,707	
2.	1951	202	80	29	12	20	8	251	
3.	1952	30	37	50	61	2	2	82	
4.	1953	3,982	81	711	14	250	5	4,943	
5.	1954	2,182	73	519	17	300	10	3,001	
6.	1955	4,683	77	1,358	22	83	1	6,124	
7.	1956	3,416	81	713	17	83	2	4,212	
TOTAL		15,795	78	3,655	18	870	4	20,320	

TABLE 14

Damage in the Brahmaputra Basin during 1950-56

S. No.	Year	Damage to crops: In lakh rupees	Damage to crops: Per cent of total damage	Damage to houses: In lakh rupees	Damage to houses: Per cent of total damage	Damage to public utilities: In lakh rupees	Damage to public utilities: Per cent of total damage	Total damage in lakh rupees	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	1950	260	68	104	27	20	5	384	
2.	1951	223	48	221	48	21	4	465	
3.	1952	200	47	194	46	31	7	425	
4.	1953	35	35	31	30	35	35	101	
5.	1954	1,923	72	433	16	315	12	2,671	
6.	1955	297	51	53	9	231	40	581	
7	1956.	310	84	13	3	47	13	370	
	TOTAL	3,248	65	1,049	21	700	14	4,997	

TABLE 15

Damage in the North Western Rivers Basin during 1950-56

S. No.	Year	Damage to crops		Damage to houses		Damage to public utilities		Total damage in lakh rupees	Remarks
		In lakh rupees	Per cent of total damage	In lakh rupees	Per cent of total damage	In lakh rupees	Per cent of total damage		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	1950	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
2.	1951	1	100	N.A.	Nil	N.A.	Nil	1	
3.	1952	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
4.	1953	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
5.	1954	102	67	50	33	N.A.	Nil	152	
6.	1955	2,107	45	2,239	48	350	7	4,696	
7.	1956	1	10	1	10	8	80	10	
	TOTAL	2,211	45	2,290	47	358	8	4,759	

TABLE 16

Damage in other River Basins during 1950-56

S. No.	Year	Damage to crops		Damage to houses		Damage to public utilities		Total damage in lakh rupees	Remarks
		In lakh rupees	Per cent of total damage	In lakh rupees	Per cent of total damage	In lakh rupees	Per cent of total damage		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	1950	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
2.	1951	269	90	3	1	26	9	298	
3.	1952	7	5	44	32	86	63	137	
4.	1953	7	58	Nil	Nil	5	42	12	
5.	1954	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
6.	1955	922	77	187	16	87	7	1,196	
7.	1956	309	66	143	30	18	4	470	
	TOTAL	1,514	72	377	18	222	10	2,113	

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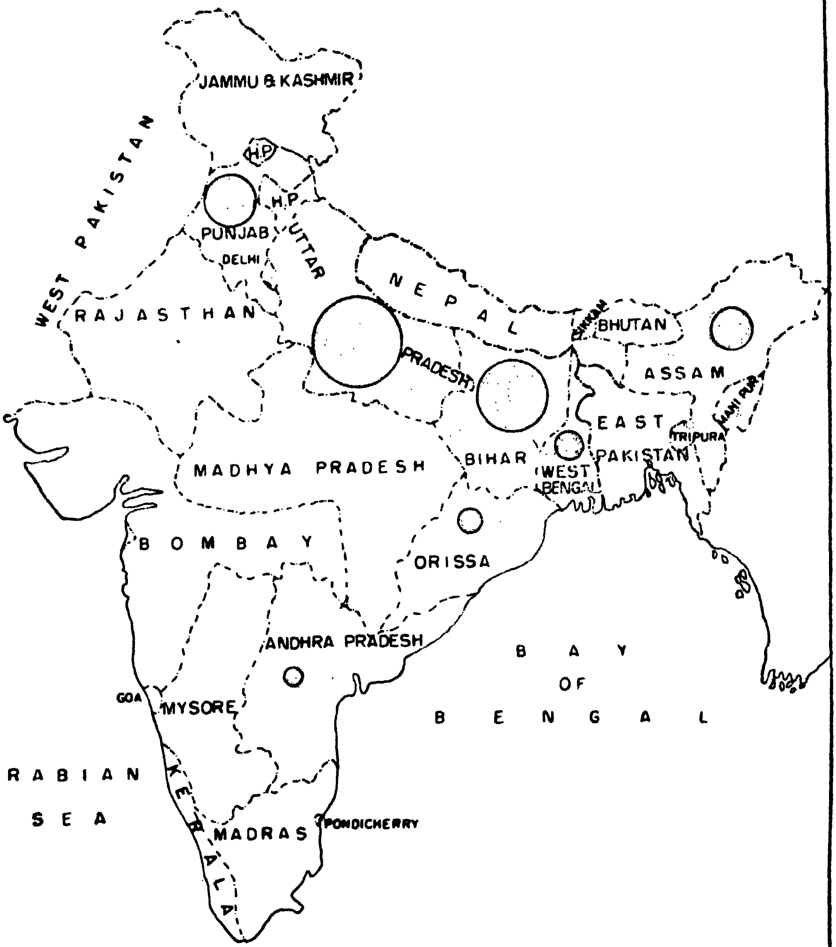
FIG. I

TOTAL FLOOD DAMAGE (IN LAKH RUPEES)

IN VARIOUS STATES DURING 1950–56.



REPUBLIC OF INDIA

100 50 0 100 200 300 MILES

T BY— R.C.R.

FIG. 2

DISTRIBUTION OF TOTAL DAMAGE IN INDIA

DURING 1950 TO 1956

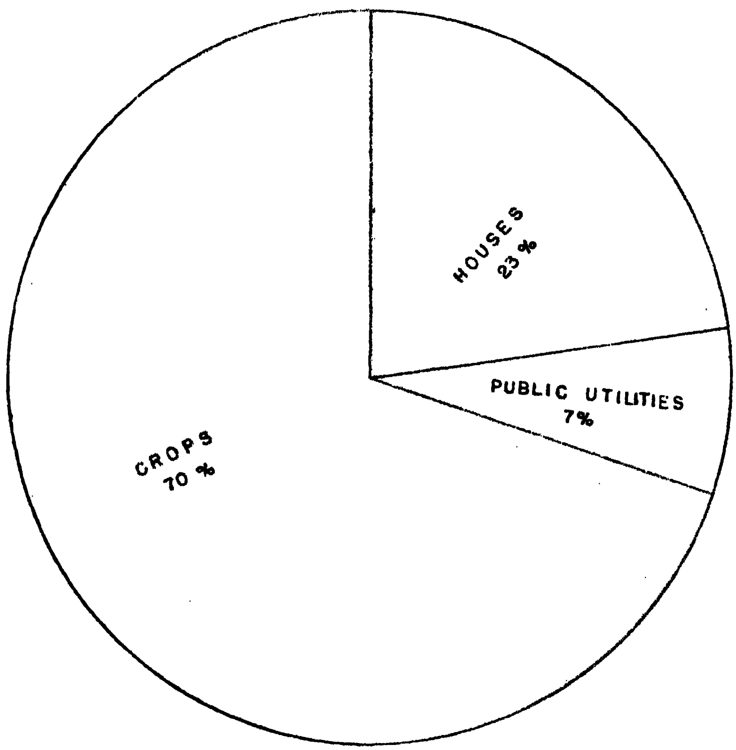
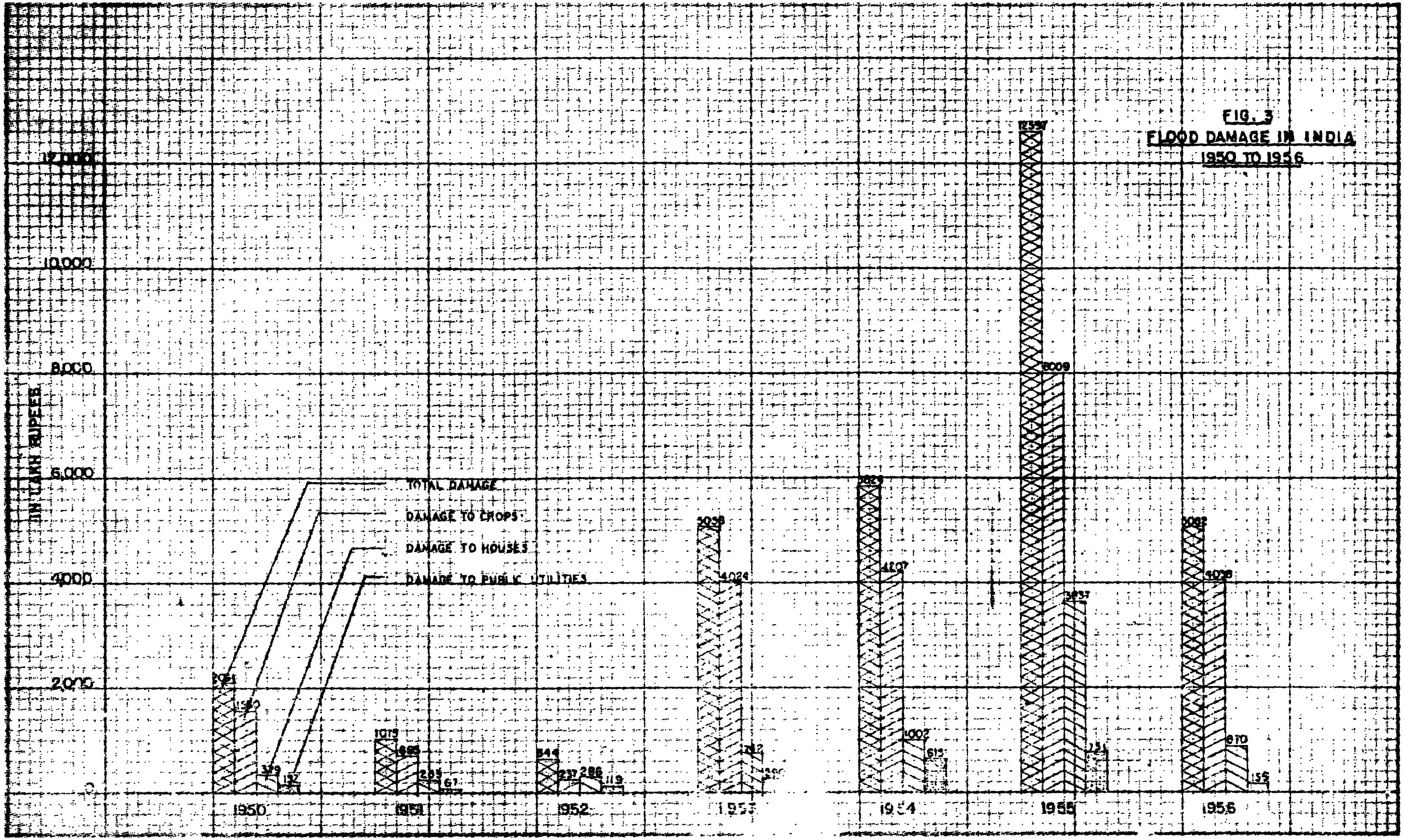


FIG. 3

FLOOD DAMAGE IN INDIA

1950 TO 1956



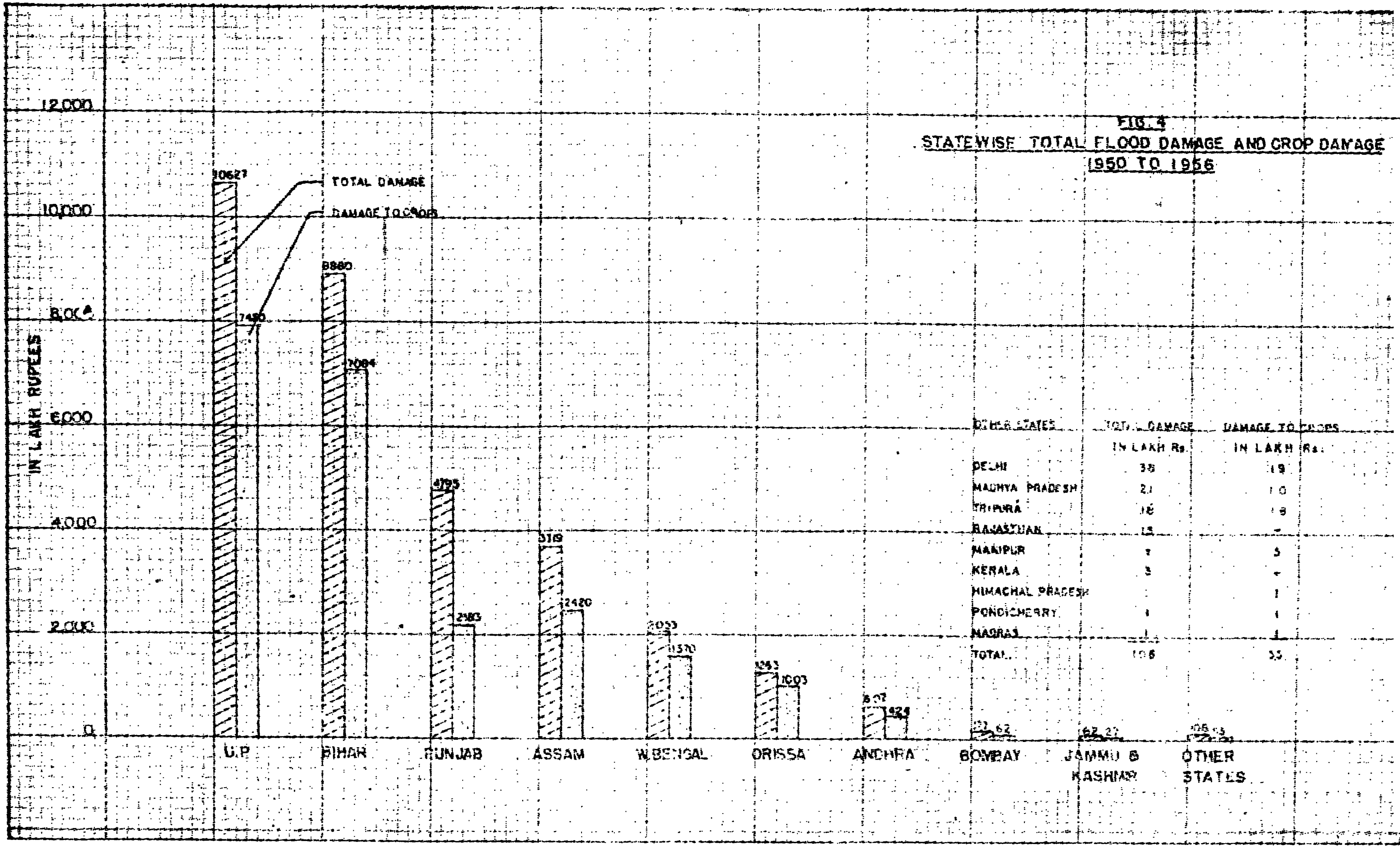


FIG. 4

STATEWISE TOTAL FLOOD DAMAGE AND CROP DAMAGE 1950 TO 1956

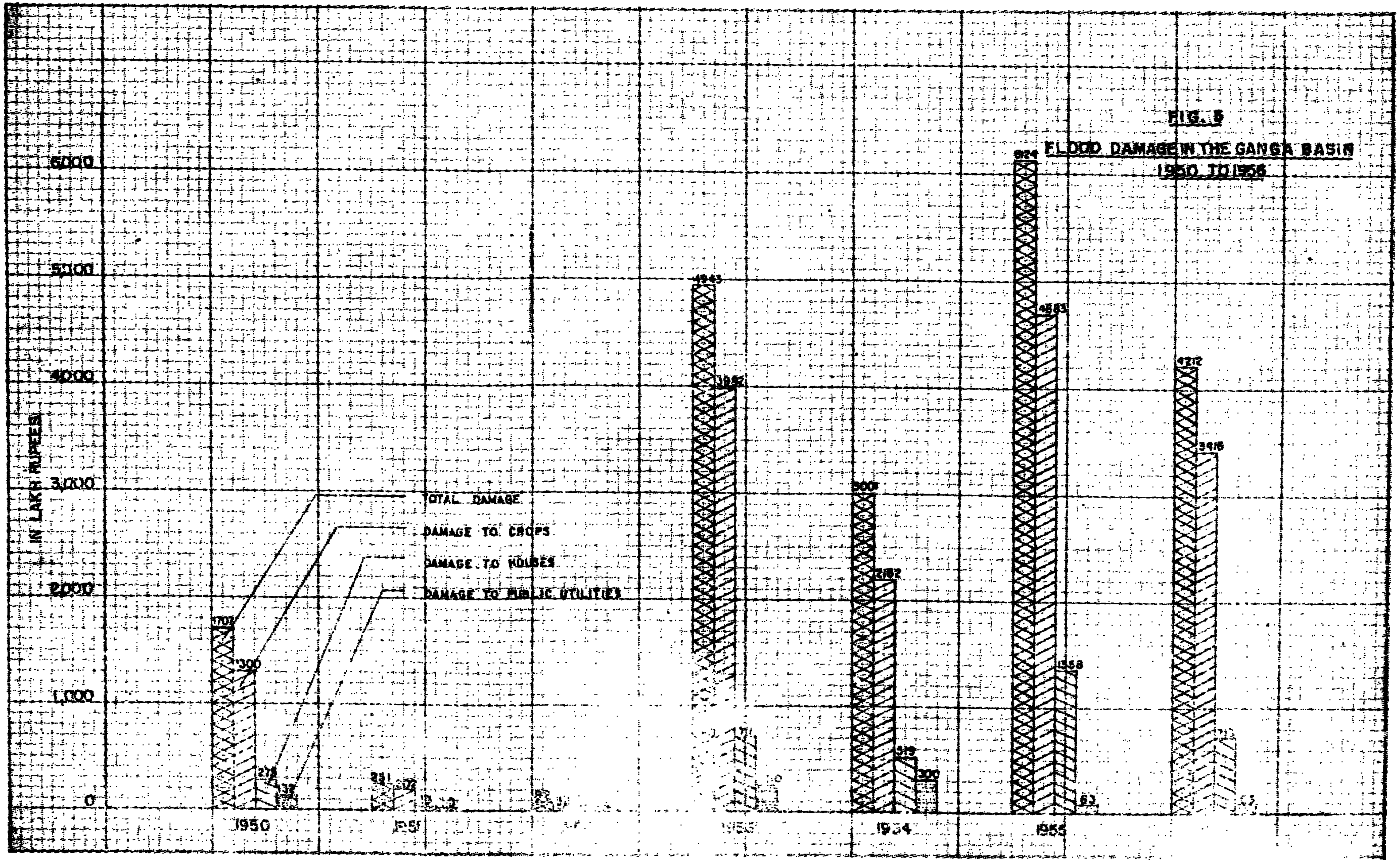


FIG. 5

FLOOD DAMAGE IN THE GANGA BASIN

1950 TO 1956

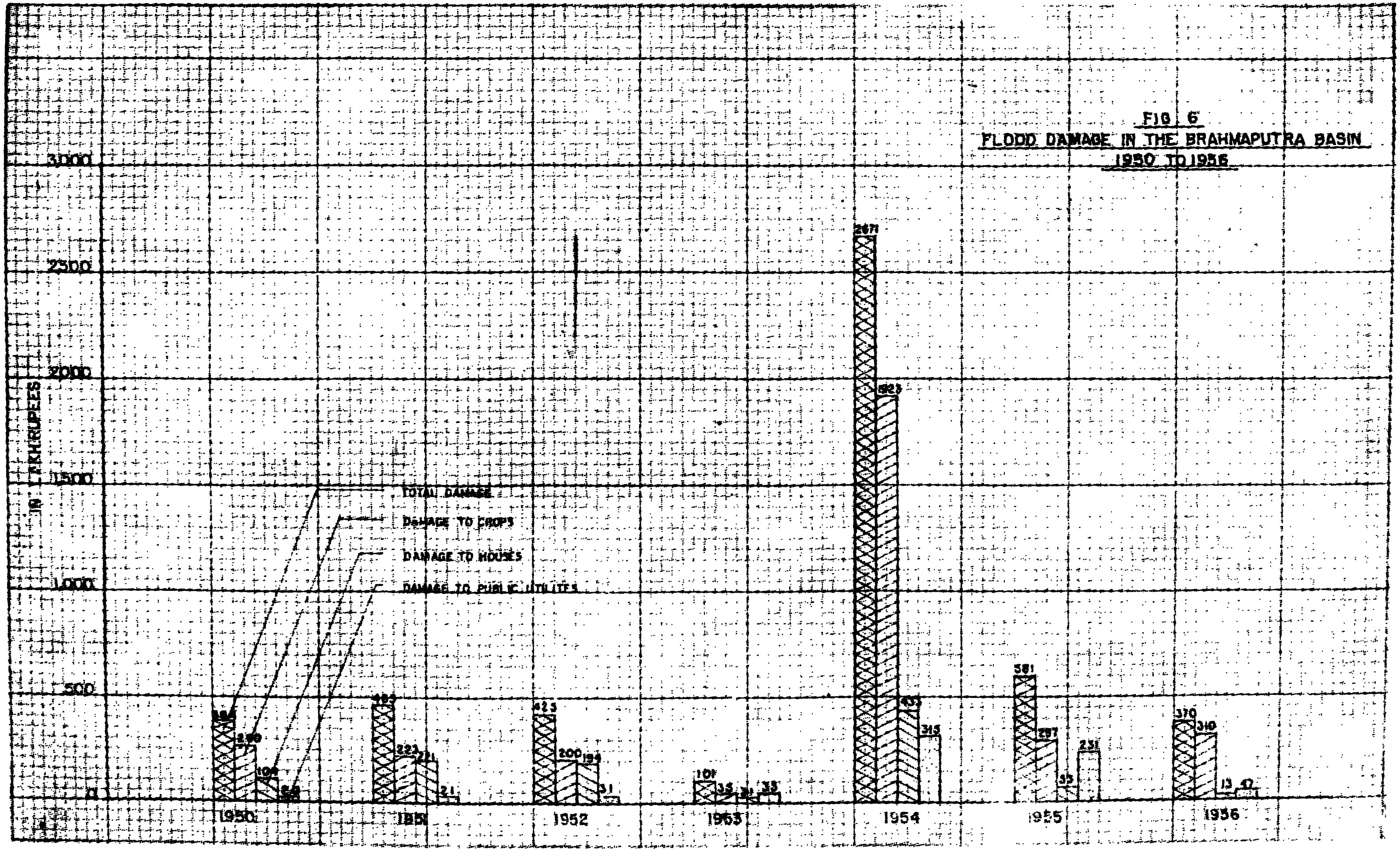
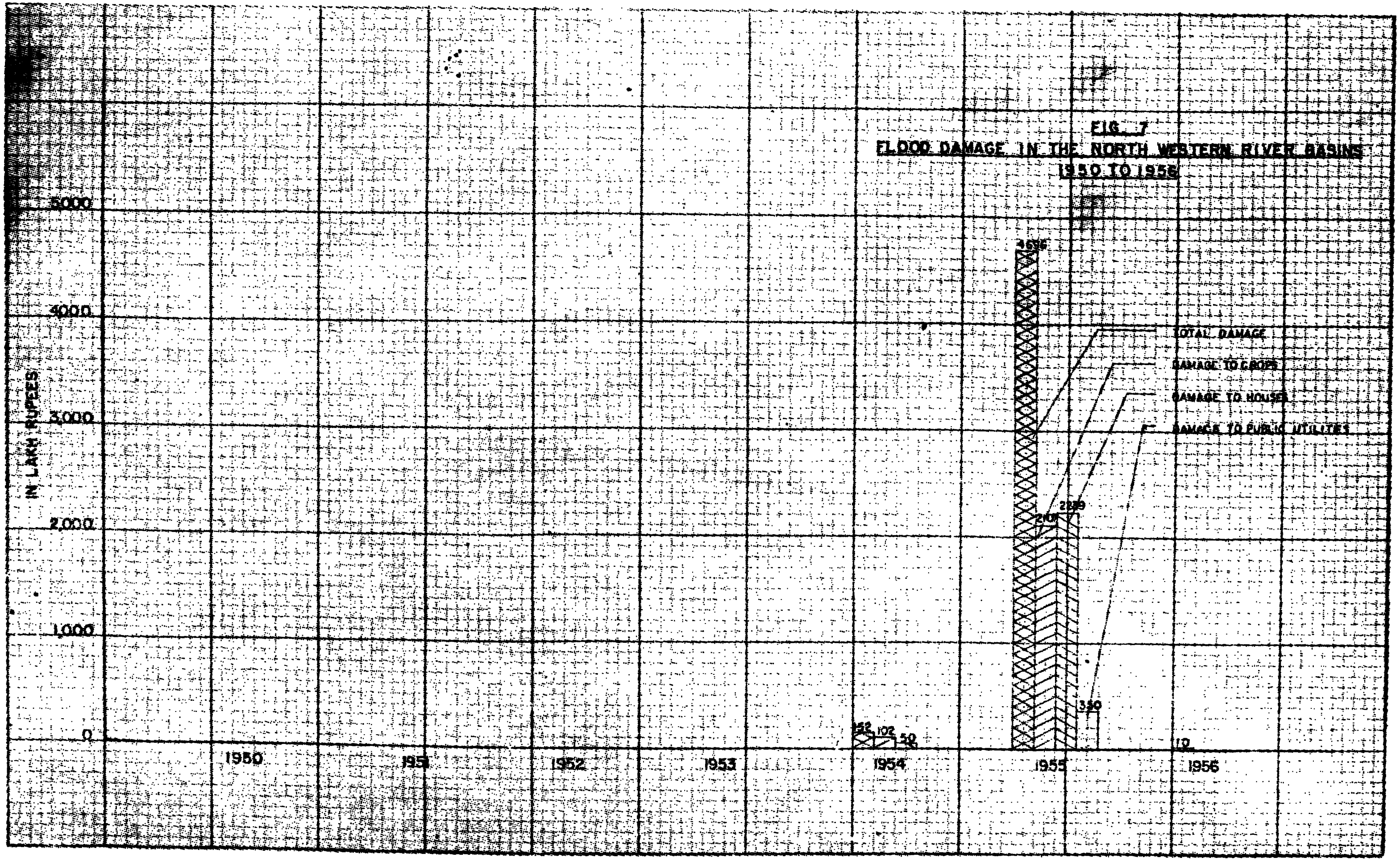


FIG 6
FLOOD DAMAGE IN THE BRAHMAPUTRA BASIN
1950 TO 1956

FIG. 7

FLOOD DAMAGE IN THE NORTH WESTERN RIVER BASINS 1950 TO 1956



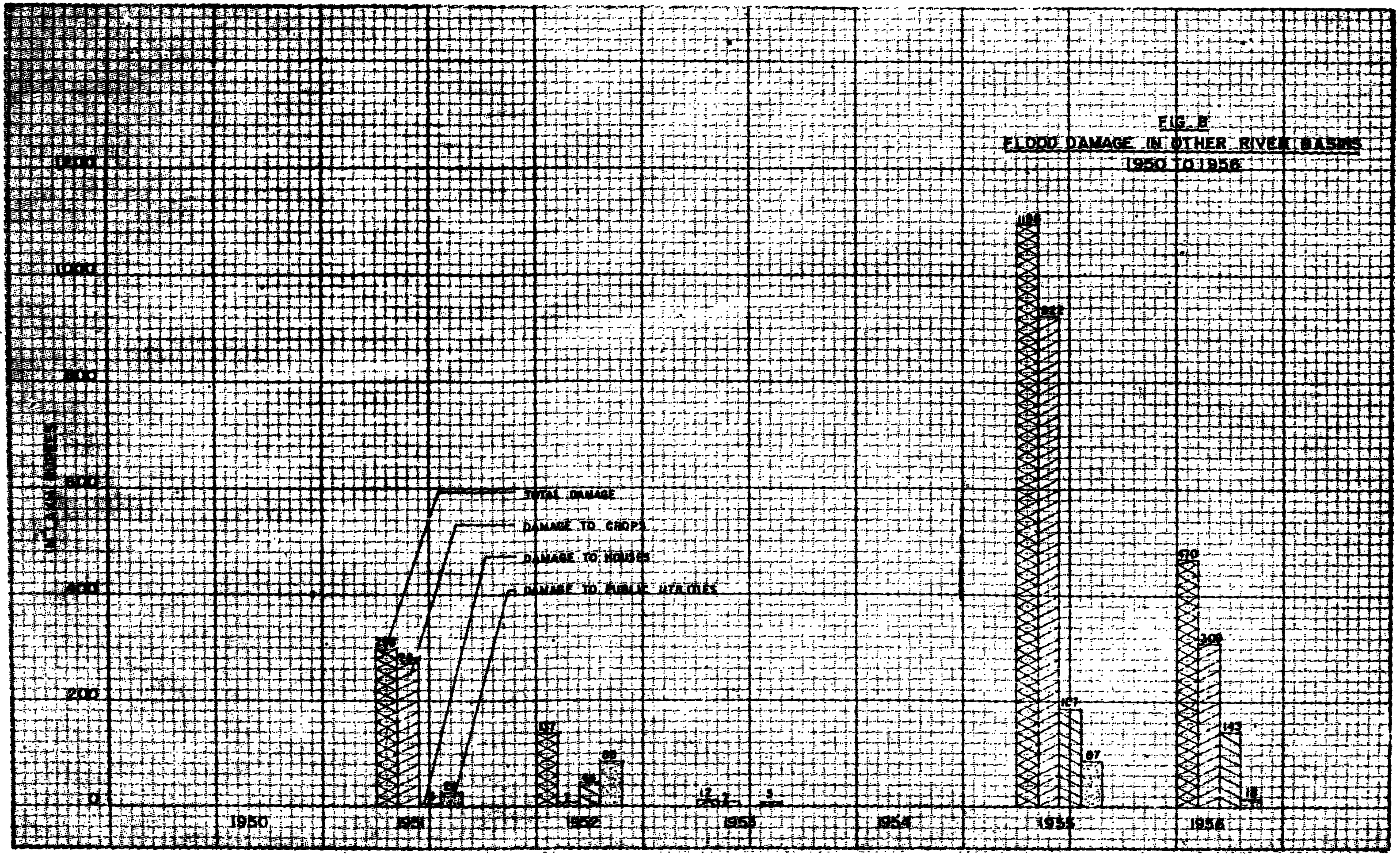
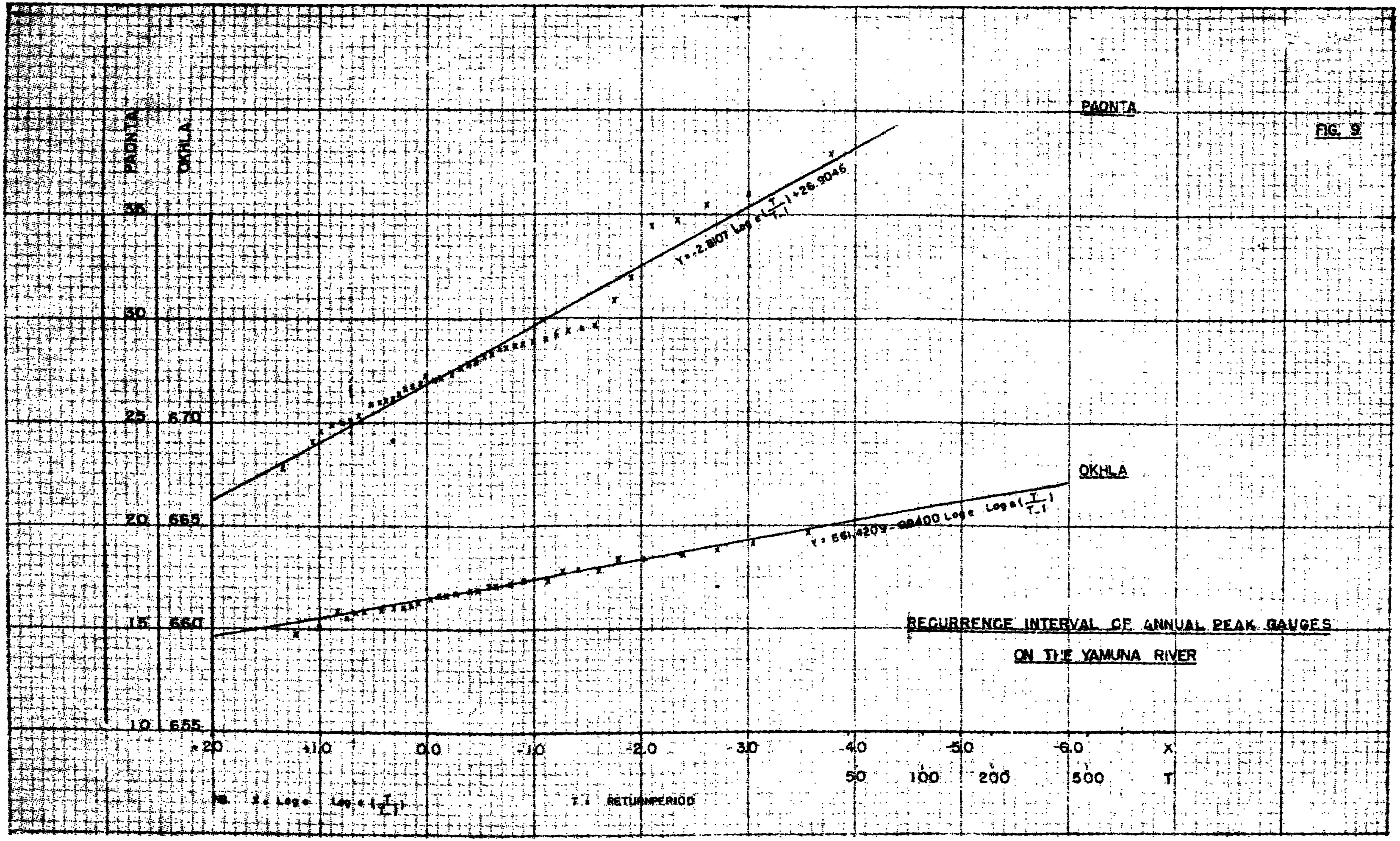


FIG. 8
FLOOD DAMAGE IN OTHER RIVER BASINS
1950 TO 1956
TOTAL DAMAGE
DAMAGE TO CROPS
DAMAGE TO HOUSES
DAMAGE TO PUBLIC UTILITIES
0
200
1000
1950
1951
1952
1953
1954
1955
1956
470
308
143
87
18

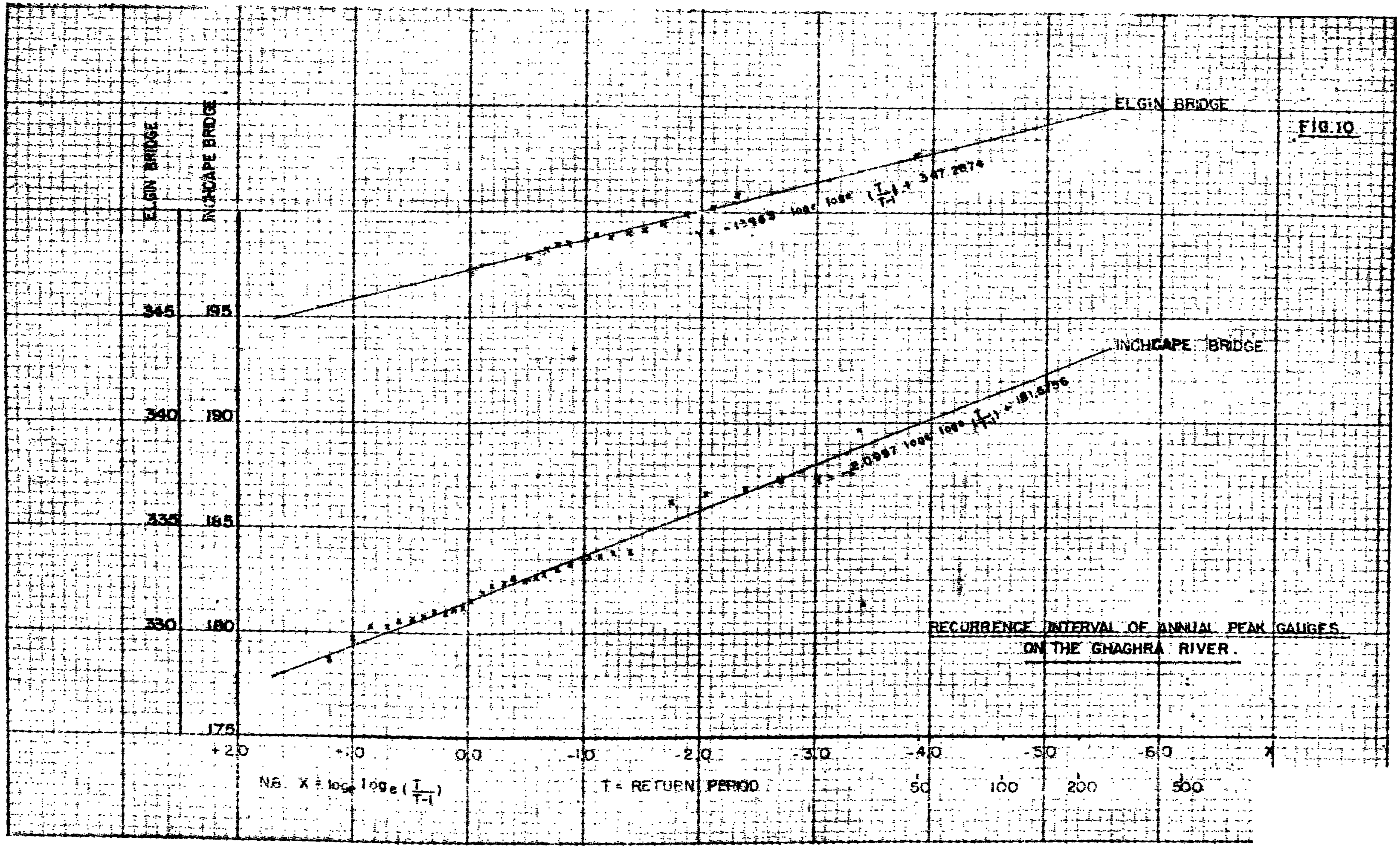
FIG. 9



RECURRENCE INTERVAL OF ANNUAL PEAK GAUGES

ON THE YAMUNA RIVER

FIG. 10



RECURRENCE INTERVAL OF ANNUAL PEAK GAUGES
ON THE GHAGHRA RIVER.

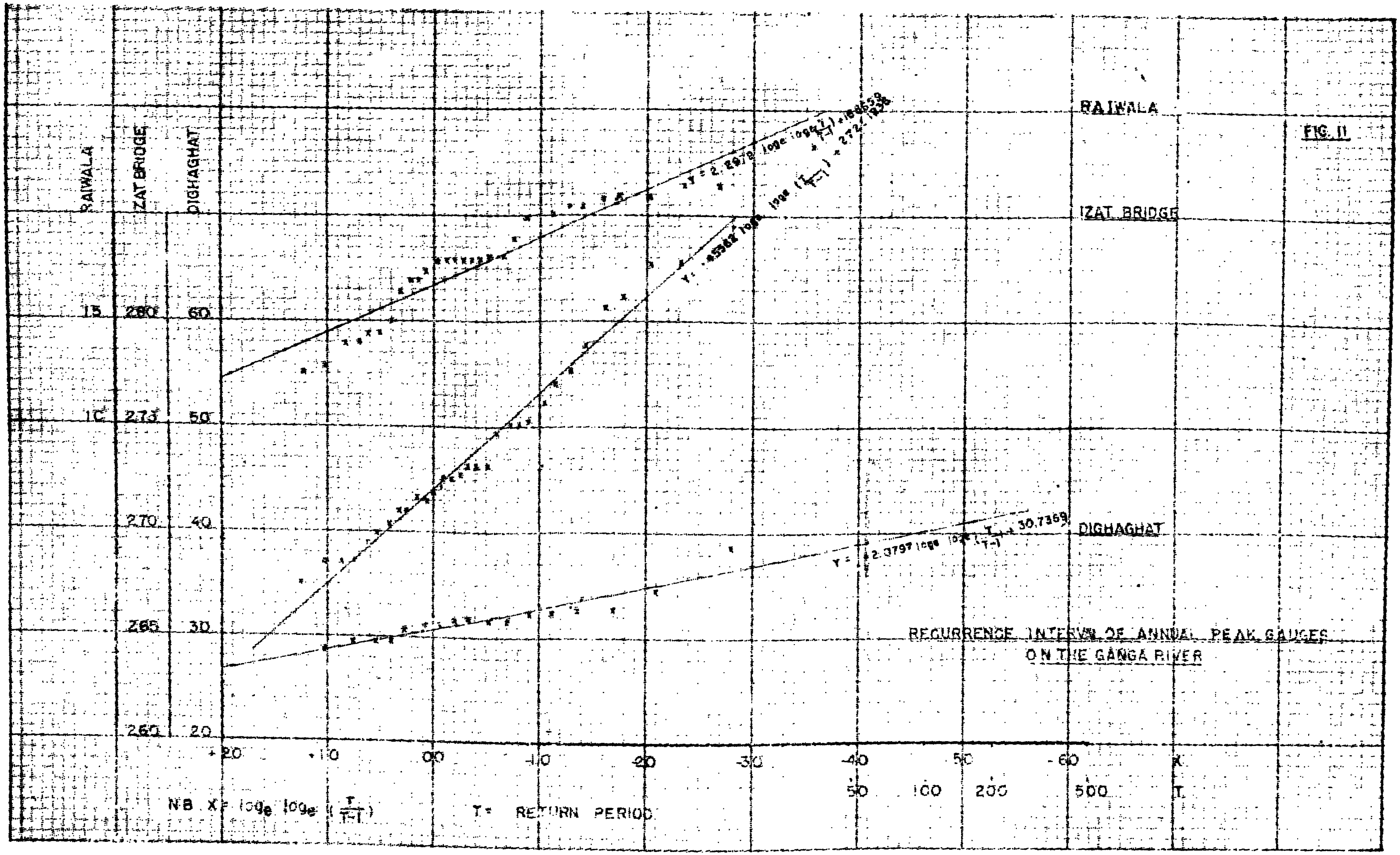


FIG. 11

RECURRENCE INTERVAL OF ANNUAL PEAK GAUGES ON THE GANGA RIVER

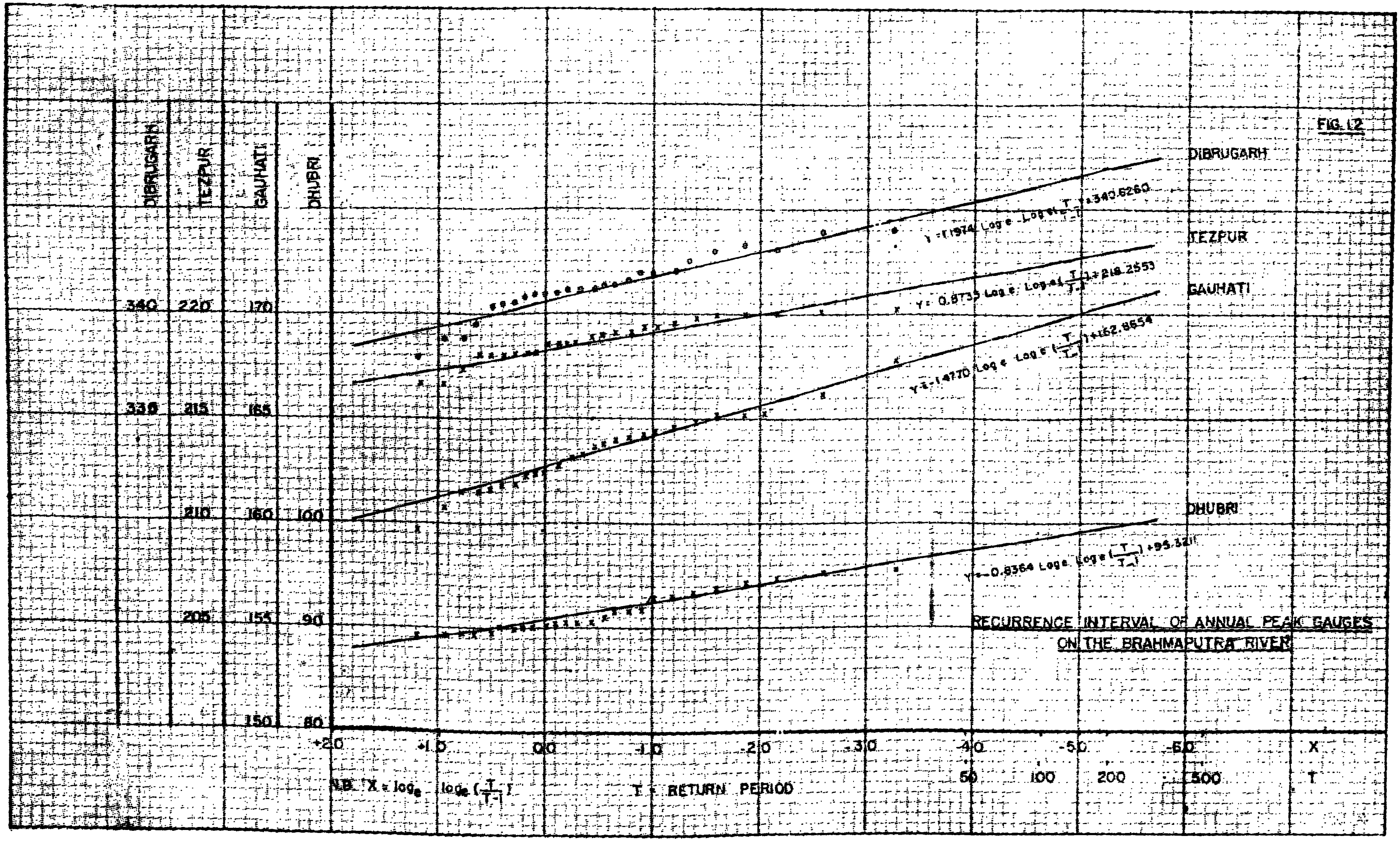


FIG. 12

RECURRENCE INTERVAL OF ANNUAL PEAK GAUGES ON THE BRAHMAPUTRA RIVER